Food and Agriculture Organization of the United Nations

CIHEAM

Proceedings of the Scientific Consultation and High-Level meeting on Red Palm Weevil management

29-31 March 2017, Rome, Italy

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Red Palm Weevil management

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Abbreviations

CIHEAM	International Centre for Advanced Mediterranean Agronomic Studies
DG	Director General
EPFs	Entomo-pathogenic Fungi
EPN	Entomo-pathogenic Nematodes
EPPO	European Plant Protection Organization
FAO	Food and Agriculture Organization
FAO-CIO	FAO-Chief Information Officer Division
GIS	Geographic Information System
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
KSA	Kingdom of Saudi Arabia
LIBS	Laser Induced Breakdown Spectroscopy
M&E	Monitoring and Evaluation
MoA	Ministry of Agriculture
NENA	Near East and North Africa
NGO	Non-Governmental Organization
NEPPO	Near East Plant Protection Organization
NIRS	Near Infrared Spectroscopy
NPPO	National Plant Protection Organization
PRA	Pest Risk Analysis
QGIS	Quantum Geographic Information System
RBM	Result Based Management
RFID	Radio Frequency Identification
RPW	Red Palm Weevil
RNAi	Ribonucleic acid-interference
TCP	Technical Cooperation Program
TF	Trust Fund
TMS	Trapping Management System
UAE	United Arab Emirates
UAVs	Unmanned Aerial Vehicles
USD	United States Dollar
UTF	Unilateral Trust Fund

A. Final report of the Scientific Consultation and High-level meeting on Red Palm Weevil management

Summary

The Scientific Consultation was held during the first two days of the event (29-30 March). It brought together all stakeholders involved in the management of red palm weevil (RPW), *Rhynchophorus ferrugineus*. National authorities, international experts and scientists, private sector representatives and non-governmental organizations held comprehensive technical discussions on the current global situation, challenges facing the effective management of the pest and options for improving management programmes. In addition to the state of the art on current global RPW research programmes, the consultation covered advances in combating RPW by employing different integrated pest management (IPM) tactics.

The consultation also discussed the Framework Strategy for Eradication of the Red Palm Weevil that had been drafted by a team of international experts, the Food and Agriculture Organization of the United Nations (FAO), the International Center for Advanced Mediterranean Agronomic Studies (CIHEAM), the International Plant Protection Convention (IPPC) and the Near East Plant Protection Organization (NEPPO). The participants reviewed and agreed to implement the national, regional and global components of the framework strategy, as outlined below.

National programmes to contain the spread of red palm weevil and eventually eradicate this pest will be supported by the framework strategy. A charter will be drafted for cooperation and coordination of efforts at regional and interregional levels to support the integrated and sustainable management programmes to control RPW, reduce its devastating effects on the environment and food security, and alleviate the socio-economic impact on rural communities.

The Regional Programme for Red Palm Weevil management will be established to create an enabling environment for cooperation and coordination, and to assist member countries of the NENA Region in improving their management strategies and RPW management programmes. The regional programme will be hosted by the FAO Regional Office for Near East and North Africa with the support of CIHEAM, NEPPO and member countries.

The Global Platform for Red Palm Weevil management will be established to strengthen coordination, information, experience and knowledge sharing at global level. The global platform will be established with the support of FAO, CIHEAM, IPPC and other partners and member countries, and will be hosted at FAO headquarters.

The High-Level meeting held on the last day of the event (31 March) was opened by the Director-General of FAO and the Secretary General of CIHEAM in the presence of Saudi Minister of Environment, Water and Agriculture and. Minister of Agriculture of Mauritania.

The ministers, government representatives and other participants were briefed on the outcomes of the Scientific Consultation and the proposed strategy that had been reviewed and agreed.

The FAO Director-General pointed out that red palm weevil has become a global threat and demands a global strategy to eradicate it. The RPW problem requires all governments to be active participants and pledge their commitment and cooperation to stop its spread and eradicate it in the affected countries. He added that the message from the consultation is positive, in that RPW can be controlled and defeated by joint efforts at global and regional levels. FAO will coordinate the global efforts to stop and eradicate the pest.

The High-Level meeting concluded with an agreement on the new proposed strategy to fight the pest, which includes the three above-mentioned components.

Introduction

FAO, in collaboration with CIHEAM, organized a Scientific Consultation and High-Level meeting on Red Palm Weevil management at FAO headquarters in Rome, from 29 to 31 March 2017. The consultation brought together representatives of the regulatory authorities (National Plant Protection Organizations – NPPOs) and experts from countries affected by the red palm weevil, international scientists, developers of technologies involved in RPW management, farmers and other stakeholders. A total of 168 participants attended the event, including:

- 88 representatives of 32 countries from the NENA Region, Asia, Europe and Africa;
- 8 representatives of regional and international organizations;
- 10 representatives of farmers and date palm producers' associations;
- 25 international experts and speakers of the plenary sessions and side events;
- 15 experts and interested participants from different countries;
- 18 representatives of private companies (technology developers) of management of RPW;
- technical staff from FAO regional offices and headquarters and from CIHEAM.

1. Scientific Consultation

The Scientific Consultation was held during the first two days of the event (29-30 March). It brought together all stakeholders involved in the management of RPW (national authorities, international experts and scientists, private sector, non-governmental organizations) for comprehensive technical discussions on the challenges facing the effective management of the pest and options for improving management programmes.

The consultation was opened by Abdessalam OuldAhmed, FAO Assistant Director-General and Regional Representative for Near East and North Africa; Cosimo Lacirignola, Secretary General of CIHEAM; and Shoki Al-Dobai, Regional Crop Protection Officer for the Near East and North Africa Region and secretary of the event.

OuldAhmed highlighted the importance of the date palm as the cultural heritage of many nations around the world and a basic food staple for a large swathe of the population in arid zones of the Middle East and North Africa. He added that the date palm is also the main element of the sustainable oasis systems in the arid zones to secure the livelihood and food of oasis inhabitants. He also pointed out that RPW represents the most dangerous threat to date palm and other ornamental palm trees in the region. Insufficient implementation of phytosanitary standards, lack of an effective preventive strategy and insufficient monitoring of response measures has led to the failure to contain the pest so far. OuldAhmed also introduced participants to the FAO activities and projects that have been implemented to provide technical assistance to affected countries over the past seven years, and the goals and expectations of the present event.

Cosimo Lacirignola, in his address, emphasized that the Mediterranean area harbours a vast biodiversity of plant species that must be protected for social, economic and environmental reasons, and mentioned that a sustainable protection strategy against RPW is more essential than ever before to protect the entire region from phytosanitary threats. He also reiterated the 40 years of long-standing cooperation between FAO and CIHEAM and stressed the need to strengthen international cooperation to tackle cross-border pests. Lacirignola pointed out the increasing movement of quarantined pests through the globalization of trade and freedom of travel, and highlighted the ongoing technical cooperation programmes with FAO and IPPC to control them.

Al-Dobai outlined the preparations that had been made for this event, including setting up an organizing committee consisting of representatives of relevant divisions at FAO headquarters, FAO regional and subregional offices in Cairo and Tunis, the IPPC, CIHEAM and NEPPO. The committee had held 11 coordination meetings since its inception in November 2016 to facilitate arrangements for the event.

He further informed participants that the consultation would discuss the entire framework of RPW-IPM as in the agenda (Annex 1), including the challenges facing the successful management and containment of the spread of RPW, and share their experience, knowledge, innovative technologies surveillance, sustainable pest management and eradication practices. The event would culminate in a High-Level meeting on Friday (31 March 2017) where government representatives were expected to discuss and adopt a multidisciplinary and multiregional strategy that includes effective implementation of cross-border phytosanitary standards.

The opening session was followed by technical sessions for expert presentations, thematic group discussions and side events. The main topics of the Scientific Consultation were:

- the current global situation and challenges to RPW management programmes worldwide as well as in the NENA, Asia and the Pacific, and Europe regions;
- success stories and lessons learned on RPW management;
- state of the art on current RPW research programmes globally, as well as advances in combating RPW by employing different IPM tactics, including early detection, biological control, remote sensing and georeferencing, semiochemical technologies and socio-economic studies, to enhance farmer and other stakeholder participation in RPW control programmes.

1.1 First day – morning session

During this session of the first day (29 March 2017) of the Scientific Consultation, expert presentations were made on the current global situation and challenges to RPW management programmes; and management programmes and challenges to RPW control in different regions, including NENA, Asia and the Pacific, and Europe.

In the two presentations on the global situation, the speakers gave an overview of the biology, host range, geographical distribution, early detection techniques and the IPM strategy currently adopted, including the use of pheromone traps and serviceless trapping options, preventive and curative chemical treatments, phytosanitary procedures, good agronomic practices relating to the management of RPW, biological control, a novel method of microencapsulation technology developed for increasing the shelf life and tolerance to ultraviolet (UV) light of the entomopathogenic fungus *Beauveria bassiana*, and the challenges facing management practices.

The presentations highlighted success stories in the management of RPW in some countries, including Saudi Arabia, and the common challenges to RPW control in different countries, as follows:

- lack of efficient early detection methods;
- weak enforcement of quarantine measures and uncontrolled movement of the infested trees as key elements in the spread of RPW infestations;
- inability of biocontrol agents to be efficiently delivered and sustained in field conditions.

- insufficient understanding of the field behaviour of RPW.
- shortcomings in ongoing management programmes resulting from insufficient human and financial resources, labour-intensive control and high cost, lack of farmer and stakeholder cooperation, and other challenges facing management practices.

In the expert presentations on the management programmes and challenges to RPW control in different regions, emphasis was placed on RPW management on date palm for the NENA Region, coconut for Asia and the Pacific, and the Canary Islands date palm for Europe (Spain). Early detection of the pest was the main challenge in combating it in all three regions. Looking at RPW control experience in Europe, it seems reasonable that an effective RPW control strategy should originate from preventive and protective actions. Pest control should engage all stakeholders by integrating effective control means into a shared IPM. The strategy should target PRW by strengthening phytosanitary measures, considering the key-point analysis in its life cycle, evaluating its population density and dynamic, the host-plant density and its ability to create a protective environment.

- Near East and North Africa (NENA) Region

The presentation on the NENA Region described the RPW management situation, key challenges and options for improving current programmes, which may be summarized as follows:

- better involvement of farmers/stakeholders, private sector and NGOs in management programmes, through efficient awareness and training;
- enhance research efforts, particularly with regard to biological control, behaviour of RPW and early detection;
- better enforcement of quarantine measures and review of regulations on the import and export of trees and offshoots, for all types of palm;
- evaluate preventive, curative and eradication treatments;
- assess role of agricultural practices in RPW control;
- learn from successful country programmes in RPW management.

- Asia and the Pacific Region

The presentation on the situation in South-East Asia described the spread and evolution of RPW on coconut palm that has been reported in many countries of the region, including India (1891), China (1998), Malaysia (2005), Indonesia, Japan, the Philippines, Thailand and Viet Nam. Strict pre- and post-entry quarantine regimes are essential to make sure that only pest-free and certified planting material can be transported, but there are still some challenges to the enforcement of regulations and legislations. Good public awareness programmes have been implemented in Malaysia and the Philippines to share information about the pest, within the country and with other countries of the region.

The presentation recommended that the IPM programme should be strengthened by intensifying research on effective natural enemies, breeding palm varieties tolerant or resistant to the pest, and applying multidisciplinary and multistakeholder management processes.

- Europe

The presentation on the situation in Europe highlighted serious difficulties in controlling RPW, especially because of the scattered nature of *Phoenix canariensis* palm plantations (as ornamental trees) in Europe, despite European Union legislation for preventing the introduction of the plants. Although preventive and curative control actions have been carried out in infested European countries based on traditional and innovative technologies; none of these has been found to be fully effective.

Despite all the efforts and resources provided by national and EU plant protection organizations, the ability of RPW to spread and its lethal interactions with host plants, make the weevil a serious pest for economically relevant palms in southern European countries. Lack of early detection tools, weak quarantine procedures, and inefficient awareness programmes have contributed to the rapid spread of RPW on *P. canariensis* in Europe. The Canary Islands has been the only success story in Europe, as RPW was eradicated in 2013 and the islands declared free of the pest in May 2016.

Main points of the panel discussion

- Participants emphasized the role of civil society in management programmes and the need to strengthen public awareness of the risk of RPW and measures to limit its spread.
- Some points were made about appropriate trapping systems, such as the optimum density and siting of pheromone traps.
- Emphasis was also placed on more research on host plant resistance, RNAi (ribonucleic acid interference, a type of gene silencing) and RPW behaviour in relation to the temperature and other environmental factors.

1.2 First day – afternoon session

There were five presentations in this session, the highlights of which are summarized below:

(i) Draft multidisciplinary and multiregional strategy for RPW management

The proposed strategy was developed by a team of FAO, CIHEAM, IPPC, NEPPO and other international experts. The draft was based on the analysis of current

RPW management programmes in different countries and identified challenges and weaknesses. The strategy aims to support efforts and programmes of countries (national component) to contain the spread of the pest and eradicate it. It will also create a charter for cooperation and coordination of efforts at regional and interregional levels to support integrated and sustainable management programmes to control RPW, reduce its devastating effects on the environment and food security, and alleviate the socio-economic impact on rural communities.

(ii) Current state-of-the-art research and technology on RPW management

This presentation revealed that, generally, more work on the control of RPW was carried out post-1996 on insecticides, pheromone traps and biological control measures. However, some aspects have been given less attention, such as early detection and molecular studies of this pest. It was also recommended that research priorities should be focused on early detection and forecasting, insecticide delivery techniques, systemic insecticides, the insect/plant tritrophic relationship, and applied molecular cell studies.

(iii) Canary Islands success story in eradicating RPW

The main components of the Canary Islands strategy that resulted in the successful eradication of RPW involved creating visibility and awareness, legislation, training, risk evaluation and contingency plan, implementing IPM (trapping, chemical control, intensive inspections and removal of infested palms), efficient data collection, transmission and decision-making using a GIS system. RPW was reported in the Canary Islands during 2005 and an IPM strategy implemented a year later. No new infestation or captures have occurred since 2013 and the Canary Islands was declared RPW-free in May 2016.

(iv) Sustainability, application and delivery mechanism of biological control agents

This presentation indicated that although there are many references to RPW natural enemies, very few of them fulfill the requirements for further development to effectively control the pest, either by conservation or by augmentative (inoculative and inundative) biological control. Special attention was paid to entomopathogenic fungi (EPF), which are notably the most promising control agents for inclusion in RPW-IPM programmes. Several strains of EPF have been isolated from diverse naturally infected specimens of RPW in different countries throughout the Mediterranean Basin and elsewhere. Molecular studies on the diversity and relationship between some of these strains, with emphasis on *Beauveria* sp., have revealed a host-mediated spread of this EPF in the Mediterranean Basin. Most of these fungal strains have environmental competence, as revealed by their temperature, humidity and UV-B radiation requirements. Several tactics may be adopted to develop EPF for RPW control, including mycoinsecticide sprays targeting the base of the fronds and EPF-based lure and infect devices, which have shown great potential for effective control in laboratory, semi-field and field trials.

(v) Recent advances in insecticide treatments and application against RPW (chemical and natural pesticides, progress of injection technologies, new organic products)

Insecticide treatments against RPW have to be considered as an element of a global strategy focused on eradication of the pest.

It is essential to understand that the RPW does not need, as it is usually believed, the existence of previous wounds on the palm for the females to lay their eggs. The mode of oviposition as well as the specific sites for egg laying have been presented. Taking into consideration these sites, the conditions to operate efficient and targeted treatments have been described.

This presentation elaborated on the stem injection technique, chemical insecticides and natural products used against RPW.

Various aspects of the stem injection technique were described, including drilling, pressure, insecticides and healing of wounds. The need to develop protocols for stem injection to treat RPW-infested palms was also emphasized, with details of the application technique, type and concentration of the insecticide, number and placement of holes to be made in the stem, and frequency of application. Several chemicals of diverse groups are available for RPW control, and these were listed. In addition, research on new products (e.g. plant extracts, essential oils, special diatomaceous earth) is being carried out.

Main points of the panel discussion

Some points were discussed relating to the trapping system and the optimum radius of attraction of the pheromone traps, impact of chemical pesticides on biodiversity and pollination, development of resistance to chemical insecticides, inspection of palms prior to transport, certification of palm trees, importance of establishing tissue culture in the laboratory, requirement to declare a pest free area, and whether shredding of palm trunks is able to kill all stages of the weevil's life cycle?

The following recommendations were also made in the panel discussion:

- To include a specific objective on the research in the proposed RPW strategy.
- To develop a harmonized guide/manual on RPW management practices.
- To involve Asia and the Pacific and other regions in the proposed RPW strategy.
- To develop regulations for the registration of promising strains of EPF in the EU for biological control of RPW and to test natural products that could enhance palm resistance.
- To test cytomplasmic polyhedrosis virus and a tachanid parasitoid (*Lixophaga sphenophori*) of the sugar-cane weevil for RPW control.

1.3 Second day – morning session

The morning session of the second day (30 March 2017) of the Scientific Consultation was in four parts and covered advanced technologies and innovative solutions.

(i) Two presentations on advanced technologies for early detection of RPW covered a wide range of aspects relating to:

- chemical detection of infested trees by dogs or electronic nose;
- acoustic detection, which identifies the gnawing sounds of RPW larvae as they chew and move around within the infested palms;
- detection by thermal imaging based on physiological changes in infested palms, which can be sensed through inspection of the thermal spectrum of irradiation emitted from the tree canopy; and
- monitoring of RPW populations, which is often based on weevil captures in surveillance traps with a specific lure based on a mixture of RPW aggregation pheromone and plant kairomone.

These presentations emphasized that there are few externally visible signs of early infestation, and scouts trying to survey and target them must carefully inspect the palm bases or crowns to discover the symptoms of damage to individual trees. A brief comparison of the pros and cons of each available early detection technique was given. Acoustic methods were most promising in detecting larvae, but with current technology considerable skill is needed to identify where to insert the acoustic probes, followed by complex signal analysis to help distinguish RPW sounds from other insects and background noise. Examples were given of how combinations of microcontrollers with inexpensive microphone systems, or somewhat more expensive piezoelectric devices that are extremely sensitive to insect movement and feeding vibrations, can be used for auralization, storage and digital-signal processing of insect sounds in trees in field environments. Progress is also being made in the development of Matlab and other software to automate and optimize the discrimination of insect sounds from background noise on microcontroller platforms.

(ii) Two presentations on innovative solutions using modern technologies to facilitate the management of RPW were as follows:

Canary Islands experience of GIS for RPW data management and analysis

The presentation pointed out the importance of GIS to manage data (collection, transmission, management, analysis, outputs). This system included a database, mobile application, web application and web viewer. GIS was one of the essential tools and elements of planning and coordination of the RPW programme that successfully eradicated RPW in 2016 in the Canary Islands. The main roles of GIS in RPW management were:

- data and spatial analysis for optimal decision-making;
- efficient planning;

- efficient use of resources, a crucial factor for success when these are limited;
- assessment of the programme (results, achievement of objectives) from readily available quality information;
- assessment of workers;
- improvement of the programme's internal and external communications.

Innovative solutions using modern technologies for better management, control and analysis of RPW eradication

This presentation highlighted the need to set up a harmonized and standardized platform that covers not only national but also regional and global levels of management, focusing on the sharing of lessons learned, improved communications, best IPM strategies and national training and support aspects. In addition to a RPW global platform, the use of innovative solutions would further help to improve RPW management. Integration of modern technologies such as Google Earth Engine, UAVs (unmanned aerial vehicles/drones), mobile devices, GIS, Internet of Things (IoTs), smart traps and sensors, within the local context and conditions would further assist in:

- effective planning, data collection, analysis and data management;
- spatial management and visualization of the managed sites, especially for optimal decision-making;
- efficient management and optimization of human and technological resources;
- improvement in communications at national, regional and global levels.

(iii) In two presentations on advances in semiochemical mediated technologies, various trapping protocols were described with respect to trap design, trap density in the field, periodic trap servicing (change of food bait and water), pheromone lures, etc. Pheromone trapping requires periodic servicing of each trap by the replacement of fresh food and water. Due to labour constraints, transport facilities and other logistics, periodic trap servicing has become a challenge for both users and service providers. In this context, experience of serviceless trapping options from Saudi Arabia based on "attract and kill" and "electro-magnetic radiation" were presented. RPW pheromone traps capture only part of the weevil population in the field and synthetic kairomone (ethyl acetate, ethyl alcohol, ethyl propionate), when added as a component to RPW food in a baited pheromone trap enhances weevil captures. In area-wide RPW-IPM programmes, systematic collection and processing of weevil capture data is essential and provides valuable information to decision-makers to assess and validate the RPW control programme. Incorporating RPW repellents (methyl salicylate, α-pinene, 1-octen-3-ol and geraniol) in a "push-pull" strategy with pheromone trapping needs to be explored for palm protection.

(iv) A presentation on socio-economic studies and approaches for farmer involvement in the RPW control programme proposed a participatory local diagnosis in order to gain better knowledge of the socio-economic context on the following main points: role of different stakeholders, typologies of oasis and farming systems, identification of organizational weaknesses, evaluation of economic consequences of RPW damage, assessment of farmers' knowledge regarding the pest and its control.

Furthermore, to efficiently manage RPW in date palms, the presentation highlighted the need to establish a sustainable development strategy for shared oasis governance by strengthening the political, institutional and legal framework, civil society capacity building, revising the status of farmer organizations in the oasis, improving the participation and involvement of the oasis population, and strengthening the operational capacities of oasis systems management services.

Main points of the panel discussion are:

- Trapping (density, distribution within area considering infested and free area),
- Treatment of infested palms, good agricultural practices and the opportunity to look for resistant varieties,
- Operational issues of new detection technologies: service and advantages (acoustic, thermal imaging, trapping), including the cost of these technologies,
- The involvement of farmers in controlling RPW as a key element was emphasized. The importance of devising a suitable mechanism for the involvement of farm workers in RPW control, especially where the farm owners are absent,
- Feasibility of using GIS to collect data directly from traps by introducing smart traps and thus replacing human intervention. Availability of GIS for users was also discussed,
- South American palm borer, *Paysandisia archon*. This moth has been detected in some southern European countries and therefore should also be considered for monitoring and surveillance along with RPW control programmes in the infested areas. Quarantine measures should be put in place in non-infested countries.

1.4 Second day – afternoon session

This session was dedicated to thematic working group discussions on the proposed multidisciplinary and multiregional strategy for RPW management, which had been shared with member countries prior to the Scientific Consultation for review and comments. Three themes for discussion were identified:

(i) regulatory and surveillance issues;

(ii) management; and

(iii) capacity building, extension, communication and coordination.

The participants were divided into three thematic groups based on their interests for further review of the elements of the strategy and produced their final comments and recommendations for RPW management, to be considered by the expert technical panel in charge of developing the strategy, as appropriate.

These thematic sessions were followed by a plenary session where the outcomes of the working groups were presented and discussed.

1.5 Key comments and recommendations of the thematic working groups

- More emphasis should be given to research on host-plant resistance in the RPW-IPM strategy, including manipulative methods that improve the chemical resistance of host palms to RPW attack.
- There are some obstacles to the use of innovative technologies for remote sensing and mapping of RPW, such as drones, which in some countries may need special authorization for use in RPW-IPM programmes.
- Pre- and post-entry quarantine periods for palms in relation to RPW need to be standardized.
- RPW surveillance programmes, establishment of pest-free areas and reporting obligation of new cases of infestation should be based on the relevant International Standard for Phytosanitary Measures (ISPM).
- Within the infested country, movement of palm trees or offshoots should be regulated from the infested area as a phytosanitary measure, besides creating a buffer zone.
- Certified palm nurseries and tissue culture production should be supported as one of the options for supplying RPW-free palms.
- Traceability (backwards and forwards) of palm/offshoots movements is important.
- Training and capacity building (farmers, NGOs and cooperatives) is an important component of RPW management programmes.
- Further research should be carried out to improve the longevity and tolerance of insect pathogens to high temperature and UV light in the field.
- The Canary Islands case should be considered as a model for other countries to achieve success in controlling RPW. This model involves all stakeholders in the management programme where creating awareness, capacity building and training, within municipalities and companies dealing with management of urban areas, are important.
- Emerging technologies, such as the newly developed seismic sensor detection for early detection of the pest, should be further tested and validated.
- The possibility of using the cytoplasmic polyhedrosis virus, Baculovirus, and the dipteran Lixophaga sphenophori (Villeneuve) (Diptera: Tachinidae), a parasite of Rhabdoscelus obscurus, for biological control of RPW may also be

further investigated.

- Regulations should be developed for registering promising strains of entomopathogenic fungi (EPF) in the EU for biological control of RPW and to test natural products that could enhance palm resistance.
- GIS is already being used in some countries. FAO should develop this tool further to distribute to all agencies and stakeholders.

At the end of the plenary session Al-Dobai, secretary of the event, summarized the discussions of the technical sessions and presented to the audience the proposed key changes relating to the title and components of the proposed multidisciplinary and multiregional strategy. These changes are as follows:

- The new title is the Framework Strategy for Eradication of the Red Palm Weevil
- Components of the strategy include:
  - National component of the Framework Strategy
  - Regional Programme for Red Palm Weevil management in the NENA Region
  - Global Platform for Red Palm Weevil management

The Scientific Consultation ended by reviewing the comments and recommendations of the technical sessions and finalizing the draft strategy for further endorsement by the High-Level meeting.

2. High-Level meeting

2.1 Opening of the meeting

The High-Level meeting, held on the last day of the event (31 March 2017), was inaugurated by José Graziano da Silva, Director-General of FAO; and Cosimo Lacirignola, Secretary General of CIHEAM. The meeting was graced by the presence of Abdulrahman Al Fadley, Saudi Minister of Environment, Water and Agriculture; and Lemina Mint Moma, Agriculture Minister of Mauritania.

The ministers, government representatives and other participants were briefed on the outcomes of the Scientific Consultation and the proposed strategy that had been reviewed and agreed.

Da Silva highlighted the urgency of combating red palm weevil in his opening remarks. He pointed out that RPW has become a global threat, which requires a global strategy to control and if possible eradicate it. This event had been convened in order to raise awareness, develop containment strategies and step up regional and global collaboration, building on several projects that FAO and partners had already been implementing to tackle RPW. The Director-General added that the message from the Scientific Consultation is a positive one, that red palm weevil can be controlled and defeated. There are specific examples such as the Canary Islands, where a strong programme with adequate resources, systematic planning, good coordination and the involvement of all stakeholders, has led to the control and eradication of RPW. In Mauritania, a swift reaction by the national authorities involving farmers and local communities, with the support of FAO, has also led to the rapid containment of the pest.

Da Silva reiterated that the Scientific Consultation has produced a well-defined Framework Strategy for Eradication of the Red Palm Weevil. He emphasized FAO commitment to supporting the implementation of the strategy to control and eradicate RPW and called for the required political commitment, collective action and solidarity. He further urged participants to make this meeting a turning point in the fight against RPW and the protection of the date palm.

In his address, Lacirignola emphasized that the Mediterranean area harbours a vast biodiversity of plant species that must be protected for social, economic and environmental reasons, and mentioned that a sustainable strategy against RPW is more essential than ever before to protect the entire region from phytosanitary threats. The Secretary General of CIHEAM stated that a containment programme is no longer an option but a necessity in the fight against RPW. Such a programme requires an early detection system, efficient warning systems and a research programme in line with territorial needs, as well as sustainable networking to enhance complementarities and synergies. He also pointed out that CIHEAM wishes to support joint activities with partners such as FAO to contribute to improving knowledge and identifying solutions. This would ensure better living conditions for the local populations that contribute to rural economic growth by integrating adaptation strategies to their environmental constraints.

2.2 Presentation of the outcomes of the Scientific Consultation

FAO Assistant Director-General and Regional Representative for Near East and North Africa, Abdessalam OuldAhmed, presented the outcomes of the Scientific Consultation as mentioned below.

During the consultation, the participants had deliberated on:

- the current global situation and challenges to RPW management programmes, as well as in the NENA, Asia and the Pacific, and Europe regions;
- success stories and lessons learned in RPW management;
- state of the art on current RPW research programmes globally, as well as advances in combating RPW employing different IPM tactics including, early detection, biological control, remote sensing and georeferencing, semiochemical technologies and socio-economic studies to enhance farmer and other stakeholder participation in RPW control programmes.

The consultation had also discussed, revised and endorsed the proposed Framework Strategy for Eradication of the Red Palm Weevil that had been prepared by a team of international experts, FAO, CIHEAM, IPPC and NEPPO.

The framework strategy aims to support country efforts and programmes to contain the spread of this pest and eventually eradicate it.

It will also create a charter for cooperation and coordination of efforts at regional and interregional levels to support integrated and sustainable management programmes to control RPW, reduce its devastating effects on the environment and food security, and alleviate the socio-economic impact on rural communities.

The proposed framework strategy has three components, national, regional and global.

(i) National Component of the Framework Strategy

Although RPW is a challenging pest, a strategy supported with adequate human and financial resources, systematic planning, good coordination and the involvement of all stakeholders can lead to its eradication. There have been various success stories on the eradication of this pest, such as in the Canary Islands.

Another example of good management and organization in our region is in Mauritania. Here the rapid action initiated by the government, with FAO support, to control RPW, together with the IPM strategy implemented with the active participation of farmers, farmer cooperatives and other stakeholders, resulted in the pest being contained in the original foci of infestation within a year of implementing the programme, with good potential for early eradication.

The National Component of the Framework Strategy aims at improving the ongoing programmes for the effective management of RPW at country level.

- Core components of the framework strategy

Phytosanitary (quarantine) measures

Import and movement of plant material within a country are the main pathways to the introduction and spread of RPW. Prevention of the introduction of plant material is the key measure that will stop the spread of RPW through strict enforcement of the International Standard for Phytosanitary Measures (ISPM) regulations.

The strategy will help member countries to develop specific phytosanitary measures and protocols for inspection.

Early detection

Early detection is the key to the success of RPW control and eradication. Currently, early detection relies mainly on pheromone trapping and visual inspection is the most effective widely used technique.

To increase the overall efficiency and speed of detection, there is a need for further testing and refinement of promising detection technologies, such as acoustic technologies or thermal imaging, to develop a quick, reliable, cost-effective and easy-to-handle early detection device for RPW.

Surveillance and monitoring

The proposed strategy will incorporate improved surveillance and monitoring techniques based on the ISPM, including a clear time-bound survey plan, guidance for surveyors, and the human and financial resources needed.

Preventive agronomic practices

Several agronomic practices influence the incidence and build-up of RPW in the field, as well as the efficiency of visual inspection and other treatments. In this context, protocols for adopting good agricultural practices that revolve around RPW management will be standardized.

Control practices

RPW management in the field depends on many tactics. The Framework Strategy will harmonize the protocols needed for management, including mechanical sanitation, insecticide applications (chemical/natural), mass trapping, biological control, and the removal and disposal of highly infested palms.

Data management/GIS/validation

Use of GIS for data collection, transmission and decision-making constitutes an important aspect of the framework strategy, and will have global implications for RPW control and strengthen regional cooperation and coordination.

GIS was a key component of the Canary Islands success story that helped and facilitated the management programme to eradicate RPW. The strategy will develop a system for mapping data collection and management based on GIS, supported by a mobile application that will be made available for use by member countries.

- Supportive elements of the framework strategy

Stakeholder participation and involvement in RPW control programmes

Participation and involvement is crucial for successful control and eradication of RPW. The advantage of involving farmers and other stakeholders in a RPW control programme is considerable, as they are present on the farm and can assist in detecting infested palms in the early stages of an attack.

The strategy will help countries to develop a clear-cut policy on farmer/stakeholder participation and engagement in RPW-IPM programmes. Pilot projects to experiment and demonstrate the feasibility of involving farmers/stakeholders would be implemented.

Role of cooperatives, NGOs and private sector

Government agencies working with RPW-IPM programmes should establish defined linkages and coordination mechanism with cooperatives, NGOs and the private sector to make the programme more meaningful and effective. Involvement of oasis programmes in the RPW programme in the countries concerned is also recommended.

Institutional cooperation and networking

The national strategies should include a mechanism for strengthening cooperation among institutions at country level. Strong engagement and involvement of the law enforcement authorities and other stakeholder organizations is crucial for effective implementation of phytosanitary measures and limiting the spread and risk of RPW.

Capacity building, communication and extension service

The RPW-IPM national strategies should include capacity-building programmes, tailor-made for different categories of stakeholder (farmers/workers and other stakeholders) involved in the implementation of IPM.

The Regional RPW Programme will assist countries in developing capacity-building programmes and user-friendly training materials that are authentic and enhanced by the introduction of a participatory approach (as in Farmer Field Schools).

The management programmes should employ a communication and extension strategy to facilitate the dissemination of information among stakeholders through the mass media. Extension agencies in each country or region can adopt a village or group of farmers and implement the RPW control programme in its totality, showcasing the benefits to other farmers. Journalists, social scientists and economists familiar with the RPW problem can contribute to raising awareness of RPW management programmes.

(ii) Regional Programme for Red Palm Weevil management in the NENA Region

For the purpose of supporting the implementation of the framework strategy, a Regional Programme for Red Palm Weevil management will be established to create an enabling environment for cooperation and coordination, and help the member countries of the NENA Region to improve their strategies and programmes for RPW management.

The regional programme will be established and hosted by the FAO Regional Office for Near East and North Africa with the support of CIHEAM, NEPPO and member countries.

The secretariat of the regional programme will be established and hosted by FAO.

The key roles of the programme will be to:

- strengthen cooperation and coordination between member countries in early warning, information and knowledge sharing for effective management of RPW;
- assist in developing programmes, guidelines and protocols for prevention, early detection, rapid intervention and management of RPW and to support member countries in their implementation;
- provide ad hoc capacity-building programmes and technical assistance to the national RPW management programmes;
- support countries in developing harmonized phytosanitary measures and contingency planning approaches to eradicate RPW or contain its spread;
- assist in building the human and institutional capacity of the national programmes of member countries;
- support research and development programmes for promotion and validation of innovative, safe and cost-effective technologies.

Member countries should identify a national focal point for coordination, communication and representation in the regional programme.

A trust fund account will be created by FAO for the financial contributions of member countries and organizations to support the establishment, operation and activities of the regional programme.

The regional programme will conduct an annual meeting of member countries to:

- assess the annual development of the RPW situation and the efficiency of programmes at regional level;
- develop an annual plan for the region based on national and regional priorities.
- The programme will be open for partnership and cooperation with other stakeholders, including farmer cooperatives, NGOs, private companies and research institutions, for promoting the national RPW-IPM strategies, developing and validating advanced management technologies. The gender issue will be considered in this context.

(iii) Global Platform for Red Palm Weevil management

A Global Platform for Red Palm Weevil management will be established for the purpose of strengthening worldwide coordination, information, experience and knowledge sharing.

The global platform will:

- strengthen coordination between member countries in early warning, information and knowledge sharing for effective management of RPW;
- promote environmentally safer RPW management tactics to minimize the risks of control operations on human health and the environment;
- establish a repository of experts on RPW;
- facilitate the exchange of research results and innovative technologies on RPW monitoring, detection and management.

The global platform will be established with the support of FAO, CIHEAM, IPPC and other partners and member countries, and hosted by FAO. It will be open for partnership and cooperation with other stakeholders, including regional and international organizations, research institutions, NGOs and private companies.

A proposal for the establishment, operational scheme and contribution of members of the global platform would be prepared by FAO and CIHEAM and shared with all countries and organizations for their interest and contributions.

The High-Level meeting concluded with the endorsement of the new framework strategy to control RPW, which includes the three components above. The endorsement came after agriculture ministers and other government representatives, scientists, pest-control experts, farmer representatives and others had taken part in the Scientific Consultation and High-Level meeting on Red Palm Weevil management, hosted by FAO and CIHEAM. The strategy includes national interventions such as improved pest monitoring and greater involvement of farmers, as well as international efforts such as rigorous phytosanitary measures against the import of palms from infested countries.

2.3 Ministerial statements

Their Excellencies the Minister of Environment, Water and Agriculture of the Kingdom of Saudi Arabia, and the Minister of Agriculture of the Islamic Republic of Mauritania, appreciated the efforts of FAO and CIHEAM in organizing the meeting. The ministers briefed the audience on ongoing RPW control programmes and the efforts made by their governments in combating the pest, and the cooperation and assistance received from FAO. In their addresses the ministers expressed the support of their respective countries for the outcomes of the meeting.

2.4 Meeting declarations

The highlight of the High-Level meeting was the adoption of the Rome Declaration (Annex 2) to control and eradicate RPW, which recognized its devastating impact on palm trees with serious consequences for national economies, food security and rural community livelihood, as well as adverse effects on the environment;

reaffirmed the importance of collaborative efforts and commitments at national, regional and global levels to stop the spread of this devastating pest; agreed with the proposed Framework Strategy for Eradication of the Red Palm Weevil; and sought the political will and necessary commitments to implement the strategy.

Furthermore, the farming community also expressed its commitment to the participatory approach and raising awareness of for successful control and containment of RPW (Annex 3). Global leaders and representatives of private business and companies developing tools and solutions to manage, suppress, control and eradicate RPW also expressed their readiness for cooperation and partnerships to provide the tools and solutions necessary to support the implementation of the recommendations and outcomes of this event (Annex 4).

2.5 Closing remarks

The FAO Director-General, in his closing remarks, appreciated the deliberations of the two-day Scientific Consultation that paved the way for the Framework Strategy for Eradication of the Red Palm Weevil. urging the organizing committee to compile, edit and publish the proceedings of the event, and to arrange a second meeting in one of the affected countries. He informed participants that FAO would set up a Trust Fund approved by a steering committee to facilitate project-based funding for eradication of RPW. The Secretary General of CIHEAM called for regional and global cooperation to stop the spread of RPW and work towards its eventual eradication to mitigate the devastating impacts of this deadly pest on palm ecosystems worldwide.

2.6 Follow-up actions

The follow-up actions elaborated below are based on agreed next steps for the implementation of the framework strategy:

- Establishment of the Global Platform and Regional Programme for NENA
  - An official letter from the FAO Director-General will be sent to member countries to share with them the outcomes of the Scientific Consultation and High-Level meeting, and to solicit their support for the establishment of the Global Platform and Regional Programme for NENA.
  - FAO will establish the global platform with the support of CIHEAM and other interested partners. FAO will create a secretariat and allocate funds for the immediate operation of the global platform.
  - FAO will organize a coordination meeting for the establishment of the Regional Programme for Red Palm Weevil management in the NENA Region, to be held in Cairo by the end of 2017.

- Proceedings of the Scientific Consultation and High-Level meeting

  FAO will prepare proceedings on the outcomes of the event and share them with all stakeholders. The deadline for participants to prepare the full papers of their presentations is the end of April 2017, after which FAO will edit and print the proceedings.

- Research and development

  FAO will work with researchers on preparing a plan for filling the gaps in research relating to RPW management and make a proposal for filling these gaps. Research should play a major role in guiding FAO, technology developers and countries on the way forward. Private-sector technology developers should be working closely with scientists to transfer their science and research results and cost-effective technologies to be applied by farmers and professional working in the field. The plan should be presented at the 2nd Global meeting to be organized for next year.

Action

Proposal to organize a meeting with researchers by the end of March 2018, to be hosted by CIHEAM in one of their institutes.

- Organization of the 2nd Global meeting

  The next meeting should be held in 2018 in one of the RPW-affected countries of the NENA Region. FAO will contact the countries concerned to establish their interest in volunteering to host this meeting.

Action

FAO to contact countries to establish their interest in hosting the meeting. The proposed date is the end of March 2018.

- RPW trust fund account

  - FAO proposes setting up a trust fund (TF) account for eradication of RPW and to share this account with member countries, partner organizations and private companies for their contributions. The TF account will provide financial support for technical assistance to member countries, such as exchange visits of experts between countries, training activities, promotion of farmer participatory approaches to knowledge sharing and farmer involvement in management programmes, as well as supporting research activities.
  - TF will be owned and coordinated by member countries, which will make decisions on expenditure. The fund will be based on a project approach with a steering committee to ensure transparency in its management.
  - FAO will act only as secretary to operate this TF.

Action

FAO will set up the TF account immediately after this event and approach the different countries and organizations for their contribution.

3. Side events

During the Scientific Consultation, two side events were organized as outlined in the Agenda (Annex 1).

The first side event, Stop the Red Palm Weevil, was an IPPC contribution to prevent the spread of this pest. The session included three presentations:

- Lessons learned from the management of red palm weevil.
- How implementing the IPPC standards contributes to the effective management of red palm weevil.
- National and regional perspectives of red palm weevil management in the Maghreb countries.

Lessons learned on the control of RPW, successful eradication in the Canary Islands and containment in Tunisia in its original foci were highlighted.

The second side event, Bionomics-Based RPW-IPM, was organized by CIHEAM and comprised the following presentations:

- RPW as vector of bacteria, fungi and acari.
- RPW infestation eliciting a control-factor repressive environment.
- Host-plant species and management consequences over infestation, damage and control.
- Weevil larvae diet: histophagy vs plasmophagy.
- Putative glandular territories associated with RPW.

CIHEAM's role in controlling some emerging pests in the Mediterranean and Middle East countries was also highlighted during this session.

Annex 1

Agenda

The Scientific Consultation and High-Level meeting on Red Palm Weevil management

Rome, Italy, 29-31 March 2017

1- Scientific Consultation (29-30 March 2017) Venue: Green Room (Building A-122)		
Day 1		
	Morning session (9:00-12:00)	
	Opening session	- Opening statement of FAO Assistant Director-General and Regional Representative for NENA Region - Opening statement of CIHEAM Secretary General - Introductory remarks the chair of the organizing committee/introduce agenda items (*Time:20 minutes*)
	Chairperson / Rapporteurs:	
	1	The current global situation and challenges of RPW management programmes Speakers: Romeno Faleiro and Polana Vidyasagar *(Time: Presentation-20 minutes, Discussion 20 minutes)*
	2	Management programmes and challenges in RPW control in different regions - **Near East and North Africa Region** - Speaker: Abdulrahman Al Dawood - **Asia and the Pacific** - Speaker: Faridah Muhamad - **Europe** - Speaker: Khaled Djelouah *(Time: 25 minutes/presentation)*
	Panel discussion (45 minutes)	
	Afternoon session (14:00-17:00) Venue: Green Room (Building A-122)	
	Chairperson/Rapporteurs	

	3	Draft multidisciplinary and multiregional strategy for red palm weevil management Presentation of the RPW-IPM strategy for the Near East and North Africa Speakers: Shoki Al-Dobai and Michel Ferry (Time: Presentation 30 minutes, Discussion 40 minutes)
	4	Current state-of-the-art research and technologies on RPW management Presentation of the RPW expert group on assessment of recent research and technologies Speaker: Hassan Al-Ayedh (Time: Presentation 30 minutes)
	5	Sustainability, application and delivery mechanism of biological control agents (overview of available biocontrol agents, delivery methods, efficacy, cost effectiveness, case studies) Speaker: Josep-Anton Jaques-Miret and Enrique Quesada Moraga (Time: Presentation 20 minutes)
	6	Recent advances in insecticide treatments and application against RPW (chemical and natural pesticides, progress of injection technologies, new organic products) Speaker: Michel Ferry (Time: Presentation 20 minutes)
		Panel discussion (40 minutes)
Day 2		
	Morning session (9:00-12:00) **Venue: Green Room (Building A-122)**	
	Chairperson/Rapporteurs	
	7	**Overview of the early detection techniques and tools against RPW** Speakers: Richard Mankin and Victoria Soroker *(Time: Presentation 40 minutes)*
	8	**Use of remote sensing for palm tree georeferencing and GIS for RPW data management and analysis** Speakers: FAO-CIO, Rome and Moises Fajardo *(Time: Presentation 40 minutes)*

	9	**Advances in semiochemical mediated technologies against RPW** (smart traps, pheromones, kairomones, dry traps, attract and kill, repellents) Speakers: Romeno Faleiro and Polana Vidyasagar *(Time: Presentation 20 minutes)*
	10	**Socio-economic studies and approaches for farmer involvement in the RPW control programme** Speakers: Slaheddine Abdedaiem, Noureddine Nasr and Michel Ferry *(Time: Presentation 30 minutes)*
	Panel discussion (50 minutes)	
	Afternoon session (14:00-17:00) Venue: Green Room (Building A-122), Iraq Room (Building A-235) and Lebanon Room (Building D-209)	
	11	**Thematic working group discussions on the proposed multidisciplinary and multiregional strategy for red palm weevil management** *Themes* • Regulatory and surveillance issues • Management • Capacity building, extension, communication and coordination (Moderators/Rapporteurs) *(Time: 60 minutes – plenary and two other rooms)*
	Chairperson/Rapporteurs	
	Venue: Green Room (Building A-122)	
	12	**Plenary session to present outcome of the working (thematic) groups (Time: 90 minutes)**

High-Level meeting on Red Palm Weevil (31 March 2017) 10:00-12:00		
Venue: Green Room (Building A-122)		
	1	Opening Ceremony - Opening remarks of FAO - Opening remarks of CIHEAM Secretary General
	2	Presentation on the outcome of the Scientific Consultation (Assistant Director-General, FAO RNE)
	3	Ministerial statements - Saudi Arabia - Mauritania
	4	Declaration of farmer organizations (Representative)
	5	Private companies’ declaration
	6	Meeting declaration (Rome Delegation)
	7	Adoption of meeting declaration (Assistant Director-General, FAO RNE)
	8	Closing remarks by FAO Director-General
Programme of side events		
Day 1	Session	IPPC seminar – Stop the Red Palm Weevil, an IPCC contribution to prevent the spread of this pest Venue: Sheikh Zayed Centre
29 March 2017	Afternoon session: 12:30-13:30	
		1. *Introductory remarks, by Jingyuan Xia, IPPC Secretary* 2. *Opening remarks, by Mohammed Ahmed M. Alghamdi, Ambassador of Saudi Arabia to FAO* 3. *Lessons learned from the management of the red palm weevil, by Michel Ferry, Scientific Director of the Phoenix Research Station, French National Institute for Agricultural Research* 4. *How implementing the IPPC standards contributes to the effective management of the red palm weevil, by Sarah Brunel, Capacity Development Officer, IPPC* 5. *National and regional perspectives of red palm weevil management in the Maghreb countries, by Fethia Hellali, NPPO of Tunisia and Mekki Chouibani, Executive Director of NEPPO*

Day 2	Session	CIHEAM side event – Bionomics-based RPW-IPM Venue: Iraq Room (Building A-235)
30 March 2017	Afternoon session: 12:30-13:30 Moderator: Ibraheem Al-Juboori (Emeritus Professor, University of Baghdad)	
		1. *RPW as a vector of bacteria, fungi and acari (speaker Porcelli F. DiSSPA UNIBA Aldo Moro)* 2. *RPW infestation eliciting a control-factor repressive environment (speaker Scrascia M. Dept. Biology UNIBA Aldo Moro)* 3. *Host-plant species and management consequence over infestation, damage and control (speaker Al-Shalchi H.Y. State of agriculture research, Ministry of Agriculture, Iraq)* 4. *Weevil larvae diet: histophagy vs plasmophagy (speaker Suma P. Di3A UNICT)*

Annex 2

ROME DECLARATION ON RED PALM WEEVIL

We, the participants in the Scientific Consultation and High-Level meeting on Red Palm Weevil management, organized by FAO and CIHEAM at FAO headquarters in Rome, Italy, during 29-31 March 2017:

Recognize the devastating impacts of the red palm weevil on palm trees with serious consequences on the national economies, food security and rural community livelihood, as well as the adverse effects on the environment;

Recognize that despite all efforts to eradicate or effectively manage the pest, it remains a severe challenge in most of the countries due to limitations in the national programmes and the absence of interregional collaboration;

Recognize that a strategy supported by adequate human and financial resources with systematic planning, good coordination and involvement of all stakeholders, supplemented by the sensible use of new technologies, can lead to eradicating red palm weevil;

Value the efforts of FAO, CIHEAM and other partners for the initiative of organizing this first global event that brought together different stakeholders to thoroughly deliberate on the challenges, exchange the success stories and lessons learned from different regions, and come up with the Framework Strategy for Eradication of the Red Palm Weevil;

Reaffirm the importance of collaborative efforts and commitments at the country, regional and global levels to stop the spread of this devastating pest;

Agree with the proposed Framework Strategy for Eradication of the Red Palm Weevil and seek the political will and necessary commitments to implement the Framework strategy.

Annex 3

FARMERS' DECLARATION

We farmers, representatives of date-palm producer associations and professional organizations from the Near East and North Africa region participating in the Scientific Consultation and High-Level meeting on Red Palm Weevil management, organized by FAO and CIHEAM at FAO headquarters in Rome:

Would like to congratulate FAO and CIHEAM for their excellent and unique initiative to organize this important event that gathered all stakeholders concerned in red palm weevil management from different regions.

Express our great thanks to the organizers of the event for their kind invitation to this very import event and giving us such opportunity to be exposed to such knowledge and experience from different regions and to be abreast with new technologies presented in the event.

Affirm that the date palm is a key crop sustaining the life of farmer communities in the oases of the Near East and North Africa Region. And the loss of date palm constitutes the loss of income of farmers and threatens their livelihood and future of the new generations in these areas.

Emphasize the negative impact of red palm weevil on the date production and well-being and income of farmers and oasis communities.

Recognize the importance of the active involvement and participation of farmers and farmer associations in management programmes and express our commitment to promoting the participatory approach and raising awareness among farmer communities for successful control and containment of red palm weevil.

Express our readiness for cooperation and partnership to support the implementation of the recommendations and outcomes of this event.

Annex 4

DECLARATION BY THE PRIVATE SECTOR

We, the global leaders and representatives of private business and companies developing tools and solutions to manage, suppress, control and eradicate the red palm weevil, who have met in Rome at this High-Level meeting on Red Palm Weevil management convened by the Food and Agriculture Organization of the United Nations (FAO) together with the International Center for Advanced Mediterranean Agronomic Studies (CIHEAM), to seek ways of achieving world food security and, in this context, to discuss the challenges and successes leading to the effective management, containment of the spread, and ultimate eradication of this pest from specific geographies:

Would like to applaud FAO and CIHEAM for their initiative in providing all stakeholders from around the globe that are concerned or involved in red palm weevil management with an excellent venue where they can openly discuss their challenges and successes in executing integrated pest management programmes directed at this pest.

Express our gratitude to the event organizers for inviting the private sector to this High-Level meeting, and for their thoughtful preparation for the meeting, providing a clear shared platform of knowledge from whereon which to base our discussions, in a well-designed programme following a series of events that involved briefs, discussions and working sessions, in an outstanding venue that fostered the energetic and undefended sharing of technology, knowledge and experience by stakeholders from different fields of knowledge and geographical regions.

Affirm the commitment of the pest control industry to providing safer, more effective, efficient and economical tools and solutions to manage the red palm weevil, renewing the ability of the global palm industry to protect its trees and crops from this devastating pest. The loss of any single palm tree to the red palm weevil constitutes the loss of a valuable asset that impinges on the reduction of income, food security and quality of life, not only of its owner, but also of the members of that community. Compounding changes due to the evolution of red palm weevil infestations create an enduring negative effect on future generations in the affected areas.

Emphasize that cooperation in science, technology and innovation, together with uninterrupted funding of the market, are key drivers for the pest control industry to invest in research and development to provide ever safer, effective tools and solutions to control the red palm weevil. These are constantly evolving to provide easier to use, less expensive and more efficient management solutions that are relevant to every stakeholder. It is important for the success of local red palm weevil management programmes that the legislation and regulatory agencies in the geographical regions support the rapid and unobstructed registration of new tools and solutions, so that they can be available in the market.

Recognize the importance of the active involvement and participation of the pest management industry in management programmes and we express our commitment to the research and development of more effective and efficient tools and solutions that are sustainable, operationally viable and easy to use for the successful control and containment of red palm weevil.

Express our readiness for cooperation and partnership to provide the tools and solutions necessary to support the implementation of the recommendations and outcomes of this event.

Annex 5

List of participants

NENA COUNTRIES:

ALGERIA

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Ministry of Agriculture, Animal, and Marine Wealth
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MAURITANIA

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Minister for Agriculture
Ministry of Agriculture
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Fouad Moctar Nech
Directeur and Joint Cabinet PM
Nouakchott, Mauritania

Diye Mohamed Teyib
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Sidi Mahmoud Doussou
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B. Framework strategy for eradication of RPW

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1. Introduction:

Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) is a key pest of palms originating from South and South East Asian Countries that has significantly expanded its geographical and host range during the last three decades. In the Near East RPW is causing wide spread damage to date palm *Phoenix dactylifera* L., having both agricultural impacts on the palm production, which has negative repercussions on the livelihoods of farmers and environmental impacts. In North Africa, it is also present (except in Algeria) but for the moment only in few limited spots, only on the Canary Island palm *P. canariensis*. Even when these spots are located on the Mediterranean coast, they represent a serious threat for the Southern oasis.

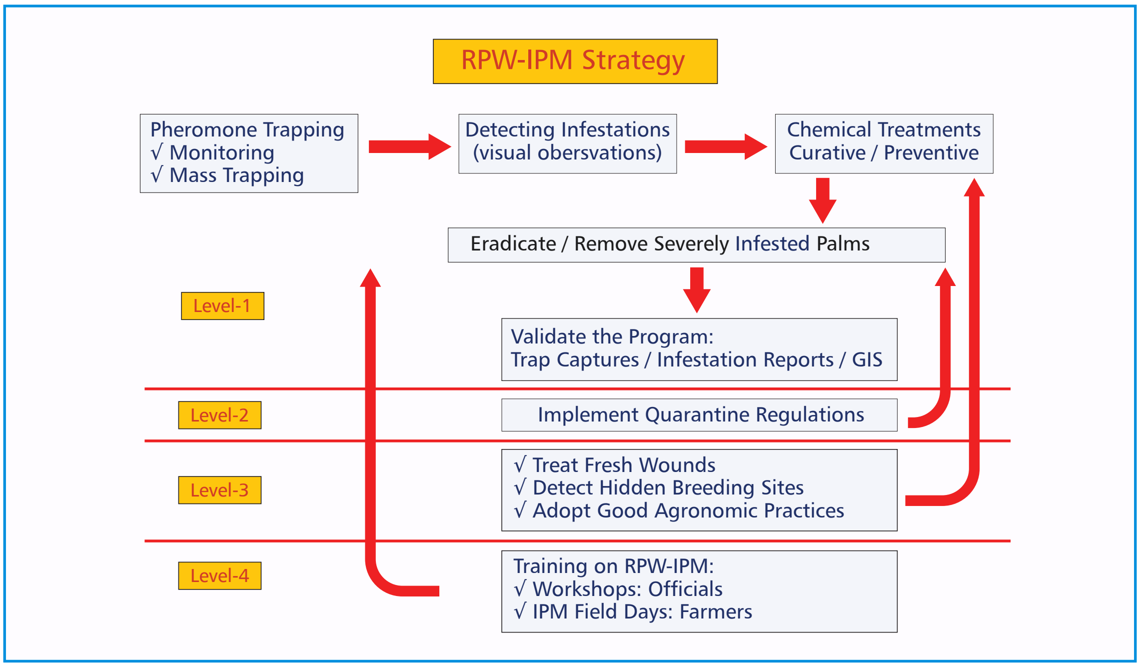
RPW is a quarantine pest in the Near East and North Africa (NENA) countries, as well as in countries in Latin America, it is the object of emergency measures in the European Union, and is considered a quarantine pest that should be regulated in EPPO countries as it is considered of limited distribution (A2 pest)[1]. Weak quarantine procedures and difficulties in the early detection of RPW-infested plant materials have contributed to its rapid spread. RPW has been spreading globally and has not been effectively managed in spite of several efforts and resources provided by countries and organizations. Extensive research has also been conducted on the management of RPW.

2. Rational

Many control means based on conventional and innovative technologies are today put in place, organized into several control actions or management strategies depicted in Figure 1. However, the failure to manage RPW in most of the countries can be attributed to the lack of awareness and systematic and coordinated control actions or management strategies that involve all stakeholders, which is related to inadequate human and financial resources available to combat the pest.

1 RPW has been added to the EPPO A2 List in 2006 on the basis of a Pest Risk Analysis (PRA) performed by Spain. The full PRA and the PRA report are available at:
https://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRAdocs_insects/04-10743%20PRA%20Rhyncho%20ferruginus.doc
https://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRAdocs_insects/04-11057%20PRAss%20rep%20RHYCFE.doc

Figure 1. Major components of the Red Palm Weevil integrated Pest management strategy



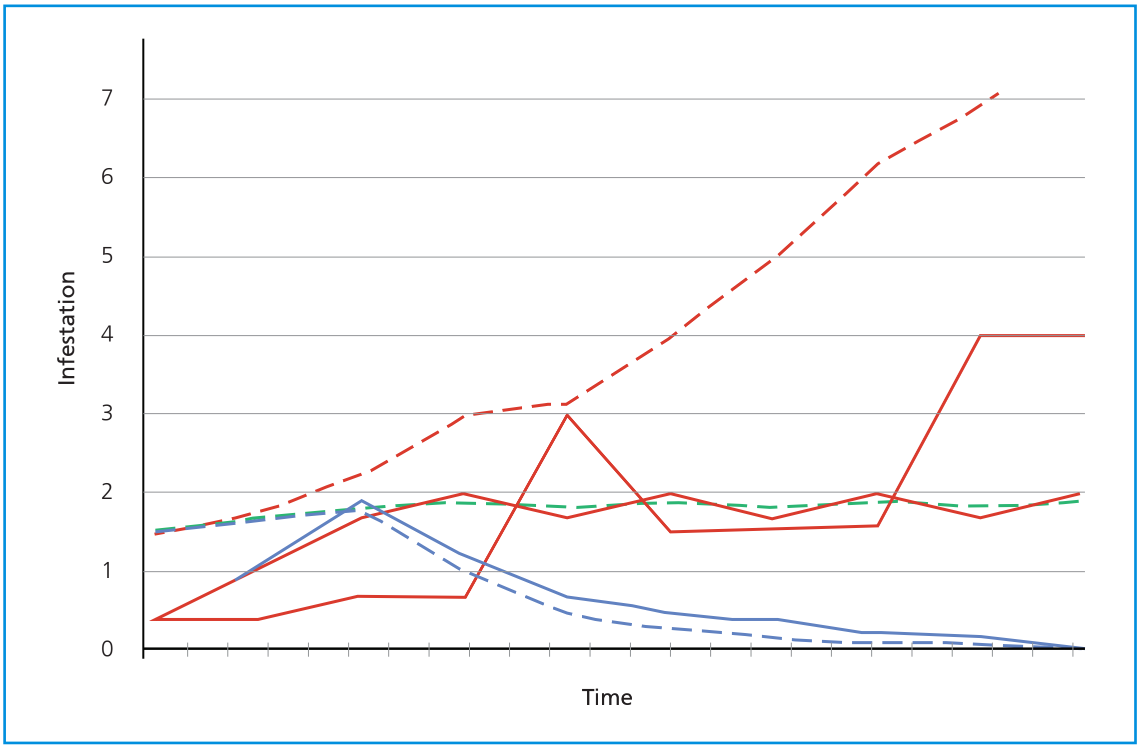
The strategy supported with adequate resources, with systematic planning, good coordination and involvement of all stakeholders can lead to the eradication of RPW as witnessed in the Canary Islands of Spain, where the pest is eradicated since 2013 and the last foci was declared free of RPW during May, 2016. In Mauritania, quick action initiated by the Government with support of FAO to control the pest and the IPM strategy implemented with active participation of the farmers, farmer cooperatives and other stakeholders has resulted in RPW being contained in the original foci of infestation within a year of implementing the program, with a good potential for early eradication.

The needs to control the pest are directly correlated with the evolution of the RPW populations (Fig. 2). Three scenarios are then possible depending on the means made available to control the RPW, considering of course that organizing and techniques are optimum and similar for the three scenarios:

- The means are superior to the needs (blue line). This is the wining scenario: the RPW populations will decrease irreversibly and rapidly;
- The means remain more or less equal to the needs. The populations of RPW remain more or less constant. RPW can be considered under control but each year a certain percentage of palms are lost. It is difficult to speak of a tolerance threshold in the case of the RPW because the pest not only affect the production but kills the trees. The percentage of lost palms year after year can be considered acceptable in case of big plantations but not at all for the small ones.

- The means are inferior to the needs. This is the losing scenario. Populations of RPW follow an exponential growth. Necessary means to control the pest should also grow exponentially and the gap between needs and means is rising inexorably. It is a useless and lost race.

Figure 2. Three scenarios of RPW control showing the relationship between available means (solid line) and required needs (dotted line) and the results that can be expected: means are greater than the need (blue), means are equal to the need (green), means are less than the needs (red)



In addition to the above factors, there are also several biological and organizational factors hindering the success of the control strategies, such as:

Biology of the pest:

- Difficulties in early detection of infested palms due to the hidden/cryptic bionomics of the pest.
- Difficulties in implementing control treatments as the larvae life cycle takes place totally inside the palm tissue and the adults hide at the base of the leaves.

Pest management aspects:

- Late detection of infested palms because of insufficient frequency inspection activity.

- Improper assessment of the risk presented by infested palms that lead to unnecessary and costly measures of palms eradication.
- Unique morphology of the palm species that creates difficulties in implementing control practices.
- Lack of effective natural enemies under field conditions that could contribute to the reduction of the weevil population.
- Difficulties to manage a mass trapping network.
- Application of the management program in a haphazard manner.
- Difficulties in effectively managing the pest in small family gardens that represent the dominant of NENA farming system in oasis, in neglected plantations and in urban environments and in urban environments (North Africa infested spots).
- Improper transfer and disposal of severely damaged/infested palms.

Regulatory, coordination and awareness aspects:

- Illegal/unregulated movement of infested palms within the country and between countries.
- Inadequate farmer and other stakeholder involvement in the control program.
- Insufficient knowledge on the RPW socio-economic and environmental impacts and on the date palm farming systems and farmer's organization.
- Unused GIS at the local and national level to have an updated knowledge of the evolution of the situation, to organize and control the activities to assess the effectiveness of the control strategy and for decision support.
- Lack of digitalized maps with the location of all the palms in the infested countries.
- Shortage of resources for implementing a comprehensive management program.
- Weak in-country cooperation and coordination between the stakeholders and also at a regional level.
- Poor implementation of phytosanitary (quarantine) measures for transfer of planting materials for new farms or gap filling in existing farm, between regions with in the country
- Inadequate protocols and certification for export /import of ornamental and exotic palms.
- Lack of public awareness on the risk associated with RPW in a broad sense.

Over the years, FAO has provided technical assistance to enhance cooperation and knowledge sharing between countries in the NENA Region, and to strengthen the capacities of the countries for the management of RPW to reduce and prevent its spread. However, to enhance the coordination and cooperation between the countries and tackle the issue of RPW at a higher level, FAO called for a 'Scientific Consultation and High Level meeting' to come up with framework strategy for eradication of red palm weevil. The strategy is developed based on the participatory approach involving the RPW international experts with contribution and participation of the national experts and representatives of the plant protection regulatory authorities from the affected countries and relevant organizations.

3. Objectives of the framework strategy:

The overall objective of this strategy is to support efforts/programs of countries to contain the spread and eradicate the pest. The strategy will also create a framework for cooperation and coordination of efforts at the regional and inter-regional level for supporting the integrated and sustainable management programs to control RPW; and to reduce its devastating effects on the environment and food security, and socio-economic impact on rural communities.

The specific objectives are:

- To provide technical assistance and guidance for improvement of the national RPW control programs/strategies.
- To establish a platform and mechanism for strengthening the cooperation and coordination of the countries at the regional and inter-regional level for the effective management of RPW.

4. Components of the proposed framework strategy:

Based on the analysis of the current management programs of RPW in different countries and identified challenges and weaknesses, the proposed strategy has two components to effectively address the problem of RPW at the country (national program) and regional (platform/program) level.

A. National component of the framework strategy:

The national component of the framework strategy aims at improving the ongoing national programs for the effective management of RPW at country level.

In the RPW infested countries, the core components of the IPM strategy involve (i) inspecting palms to detect infestations, (ii) capturing adult weevils using food baited pheromone traps, (iii) preventive and curative chemical treatments and (iv) removal/eradication of severely infested palms. It is complemented by phytosanitary (quarantine) measures to regulate the movement of planting material, capacity building and extension activities. However, the control programs currently being implemented have by and large not been successful in containing the spread or controlling the pest despite some success stories in some countries.

The failures in the control programs can be attributed to several factors, mainly related to difficulties in detecting infested palms early in the stage of attack, challenges and constraints facing application of quarantine measures and lack of awareness and commitment of farmers and other stakeholders in the control programs.

I) Action plan for improved national RPW-IPM strategy:

The proposed strategy will focus on providing the member countries with technical assistance and advice to improve the components of the RPW-IPM strategy as follows:

1. Phytosanitary (quarantine) measures

The weaknesses and constrains associated with the implementation of the phytosanitary measures can be summarized as follows:

1. Lack of knowledge on the national phytosanitary legislation on RPW.
2. Insufficient staff and means in the countries to effectively implement the regulations.
3. Illegal movement/smuggling of planting material through alternate routes.
4. Interference in the imports/movement of planting material by higher officials.
5. Lack of:
    a. Availability of sources of trustful /certified palms within the countries.
    b. Enforcement of quarantine measures.
    c. Specific regulations/guidelines on phytosanitary measures to regulate the palm trade, especially for officials / enforcement authorities at the entry points.
    d. Registered nurseries.

Specific regulations and measures (clear inspection and treatment protocols) should be developed within the phytosanitary legislation related to requirements for import as well as the movement of palms inside the countries.

Import and movement of plant material inside the country is the main pathway of introduction and spread of RPW. Prevention of the introduction of planting material, as a phytosanitary measure is the main approach that should be taken against the RPW for the countries where the pest is absent or of limited distribution.

The International Plant Protection Organization (IPPC) will play an important role in improving the phytosanitary aspects of the national RPW programs. The

IPPC is the phytosanitary standard setting organization recognized by the World Trade Organization, with 183 Contracting Parties, including all NENA countries. At the NENA region, the Near East Plant Protection Organization (NEPPO) is in charge of the regional collaboration, coordination in area of plant protection and development of the regional phytosanitary standards and strategies to monitor and control the trans-boundary plant pests.

1.1. Phytosanitary import regulations/legislations

Due to the cryptic biology of RPW, importation of palms plants should be strictly regulated. The importation of date palm offshoots and ornamental palms of more than 6 cm base diameter should be banned from infested countries. Date palm from in vitro propagation should be imported in test-tubes. Acclimatization should be done at the imported country level.

However, if a country takes the risk to import date palm offshoots or ornamental palms of more than 6 cm base diameter from an infested country, import should be authorized from free-pest areas only if the limits of these areas can be established and controlled with all necessary guarantees precisely established (50 km distance from the infested areas, traceability of all the palms in this area, absence of palms introduction for the last 3 years, no infested palms and no captures in traps for the last 3 years).

If a country accept to take the risk to import palms from free-pest areas of infested countries, importers should be registered, certified and mapped (GIS system) by National Plant Protection Organization (NPPO). They should ensure traceability and the control of the imported palms during three years. The palms should be maintained in RPW-proof quarantine facilities during one year. Inspection should be conducted by NPPO officials each two to four months.

Guidelines and procedures should be developed for strengthening quarantine inspection at borders and plant protection services within the country (including manual on identification of palms species).

1.2. Phytosanitary regulations/legislations regarding the movement of palms inside an infested country

To avoid any further potential spread of RPW, movement of palms trees should be regulated within the whole country as up-to-date, precise and controllable limits of the infested areas are not usually available. Regulations should be elaborated and implemented to assure the RPW containment.

Total ban of date palm offshoots or ornamental palms movement, except palms of less than 6 cm base diameter (from tissue culture concerning date palm) constitutes the best solution as long as the RPW is not eradicated. Nevertheless, it is not always possible to adopt such drastic measure when exists a strong demand for new palms plantations.

Movement of palms in and from free-pest area could be authorized in the same conditions as the ones proposed for importing palms. Movement of palms in and from infested area should be totally forbidden excepted if they are previously inspected, treated before transport and maintained in RPW-proof certified nurseries at least for one year. The traceability of these palms should be established during three years.

Nurseries should be registered, certified and controlled by an official institution to ensure their compliance with a certification scheme (variety authentication and free from pests including RPW).

Appropriate protocols for the palms inspection, treatments before transport to the certified nursery and for the implementation of RPW-proof certified nurseries should be developed.

In case of detection, the National Plant Protection Organization (NPPO) should delimit the infested area (at least 100 meters around the infested tree or trap that has captured a weevil), define the containment area, a buffer zone area and trace back the related plant material. These areas should be mapped and NPPO with the collaboration of the farmers, the extension agents and all concerned administrations and stakeholders should implement the appropriate measures to contain and eradicate/suppress RPW such as:

i) information of all the farmers and date palms owners in the delimited zone and adopt in collaboration with the other Ministry of Agriculture services as well as all concerned stakeholders all the measures that would facilitate the involvement of the farmers and of the palm owners in the control of the pest;

ii) frequent inspection – at least monthly - of all the palms in the infested area;

iii) implementation of a pheromone mass trapping or, at least, monitoring trapping system in the infested area;

iv) intensified survey programme in an area of at least 10 km around the infestation and to trace back the related plant material in case of a new outbreak;

v) immediate destruction or, where appropriate, treatment/mechanical sanitation of the infested palms;

vi) measures to prevent any spread of RPW during the destruction or sanitation actions by application of chemical treatments in the immediate vicinity;

vii) stop movement of nursery stock from the infested area;

viii) all these activities must be registered in a GIS and analyze weekly to control their right implementation and to assess their efficiency and the evolution of the situation.

1.3. Enhancement of the implementation of the phytosanitary legislation in countries

Enforcement of the phytosanitary regulations should be supported by:

- Training of plant quarantine staff and other law enforcement authorities.
- Development of manuals and procedures on RPW specific quarantine regulations and measures, inspection measures at borders and plant protection services within the country (including manual on identification of palms species).
- Raising awareness on RPW phytosanitary legislation and measures among all the stakeholders.
- Develop guidelines for countries to establish certified and registered nurseries that would be entitled to trade RPW free palms within the countries to avoid the illegal trade and movement of the palms.
- Support the establishment of tissue culture laboratories for the production and supply of RPW free planting material.
- Strengthen the coordination and engagement of all stakeholders (farmers/ farmer cooperatives, NGOs, MoA officials, other law enforcement agencies etc.).

2. Early Detection

In absence of reliable early detection tools, visual inspection is the only available effective technique, if properly and frequently applied. Visual inspection could be improved by adopting the following.

- Develop a harmonized technical protocol/manual with illustration for visual inspection in a simple and easy to understand languages of the farmer and other support staff/stakeholders.
- Improve farmer/stakeholders involvement, especially for this activity, in the framework of the general policy and program to involve the farmers in the RPW control program.
- Enforce clean cultivation especially related to offshoot management and frond pruning to facilitate visual inspection.
- Register the inspection activity, as all the other activities for its control and analysis in the GIS of the RPW control program.

Visual inspection concerns mainly the offshoots and the trunk basis of the date palms, when on the Canary palms is focused on the crown of more than 2-3 meters high due to the fact that most infestation of this species occurs in the crown.

The pheromone traps constitute a very useful tool to complete the visual inspection and as a tool to alert on the needs to increase inspections when traps capture RPW.

To increase the overall efficiency and speed of detection, there is a need for further testing and refinement of pipeline detection technologies, to develop a quick, reliable, cost effective, and easy to handle early detection device for RPW.

Using sniffer dogs to detect RPW infested date palms is possible, because the infestation start mainly in the offshoots and the basis of the trunk up to 2 m from the ground. Dog-assisted detection could suit well also at nurseries, ports of entry and/or quarantine facilities.

Other sophisticated detection techniques are currently available with only limited/ experimental use.

Acoustic systems have seen limited use because they require skilled operators. Simpler, lower-cost automated systems are being developed to increase the capability of early detection efforts. Also, field studies are being conducted to reduce interference from high wind that may induce leaf-rustling noise pulses difficult to distinguish from other insects' sounds.

Near infrared detection could allow to detect early infestation but field experimentation of sensors must be implemented, especially if the purpose is to use this technique with drones or planes. Infestation in Canary palms takes place at the canopy level where physiological disturbance could probably be easier to detect than with date palms that are usually attacked at the level of the offshoots or the trunk base.

Experimentation for the creation of a portable laser induced breakdown spectroscopy based technology must go on. Such equipment would be an interesting handy tool in the early detection of RPW on ground. Furthermore, high frequency radar and X-ray technology experiments have some promises based on preliminary experiments. Satellite imaging and seismic detection could be considered for experimenting. Experiments with proteomics strategies are also promising for the development of future kits.

3. Surveillance and Monitoring

Surveillance and monitoring is vital in making a timely decision for managing RPW, should an infested palm be detected or an adult weevil is recorded in monitoring traps. Surveillance services also help to evaluate the effectiveness of control actions and declaration of pest free area. Surveillance and monitoring is carried out through systematic visual inspection of palms and by using pheromone traps. This program could be improved by adopting the following:

3.1. Visual inspection:

Frequency should be:

- Non-Infested area: Quarterly
- Infested Area: Bimonthly

3.2. Trapping

Food baited bucket pheromone (ferrugineol) traps are widely used to capture adult RPW population that attract both male and females. These traps are very effective indicators of the presence and spatial spread of the pest if well serviced, in the absence of any equivalent and cost effective technology.

Trapping efficiency can be maintained through the following:

- At least Biweekly servicing (renewal of food bait and water).
- Trap Density
- Non-Infested area: Need based after risk assessment
- Infested Area: 1-2 traps / ha
- A clear protocol for the surveillance and monitoring based on the International Standard for Phytosanitary Measures (ISPM 6) should be developed, including clear time-bound survey plan, guidance for surveyors, inputs and human and financial resources needed for the program.
- Attention should be given to palm nurseries, mainly for ornamental (*P. canariensis*) for instance.
- Enhance awareness, communication and participation of the farmers/ stakeholders in the monitoring program and reporting incidence of pest.
- Develop and implement a mobile application and GIS aided monitoring system for efficient mapping, data collection, analysis and management of the surveillance and monitoring program.
- Immediate deployment of an intensive control program around 10 km radius from the newly detected infested palm/trap capturing weevils based on the information campaigns, farmers and all concerned stakeholders involvement and on the core RPW-IPM components of visual inspection of every palm, trapping, preventive treatment, quick curative mechanical treatments and quick eradication of severely infested palms.

4. Preventive agronomic practices

Several agronomic practices influence the incidence and build of RPW in the field and also the efficiency of visual inspection and other treatments. In this context, the following practices need to be adopted/studied to reduce the risk of infestation and facilitate management of the pest:

i) Offshoot management: Young date palms in the susceptible age group of less than 15-20 years often have a large number of offshoots that makes visual inspection of such palms to detect infestation extremely difficult. Regular leaves/offshoots pruning and also offshoots removal constitute an indispensable practice. Preventive soaking insecticide treatment of the offshoots and the trunk immediately after these operations is required to kill and to repeal the RPW attracted by the volatiles produced by the wounds. Furthermore, removal of offshoots without treating the wound with insecticide on the mother palm often results in gravid female weevils getting attracted to these sites for egg laying, resulting in a new infestation.

ii) Frond pruning: Wounds caused on the palm after frond shaving that are not treated with a repelling insecticide to neutralize the palm volatiles emitted, could also result in infestation by attracting female weevils to such odors. In some countries it is therefore recommended to carry out frond shaving during the winter when weevil activity is low.

iii) Irrigation method adopted: Open flood irrigation particularly in plantations where the water touches the collar region of the stem is known to attract RPW. Using controlled drip irrigation instead of open flood irrigation is therefore recommended. In homestead or landscape gardens, date palm stems should be insulated with polythene sheets at the base to prevent the splashing of water from sprinklers and other irrigation systems.

iv) Role of fertilizers in the management of RPW: Very little is known about the relationship between the RPW infestation and the application of macro (NPK) and micro nutrients (Zn,Si,Fe, Mn,Mg, soluble silica etc.). Some very preliminary results indicate that palms fertilized with diatomaceous earth could offer better resistance to infestation by RPW.

v) Palm density (spacing) in the field: Closely spaced palms, especially in the traditional grooves with limited penetration of sunlight, offers a suitable micro-climate for RPW, probably due to enhanced in-groove humidity. Adopting a higher spacing of at least 8x8m could be useful.

vi) Varietal selection: Host plant resistance is not exploited for the management of RPW. Farmers cultivate certain traditionally established date palm varieties and RPW is known to have a differential preference for palm varieties in the field. National research institutions should carry out studies to identify the factors of resistance and incorporate these in the traditionally cultivated varieties.

vii) Repellents of RPW need to be studied to prevent infestation in new areas.

viii) Preventive agronomic practices with respect to ornamental palms needs separate protocol.

5. Control Practices

RPW management in the field revolves mainly on the following control measures. All control operations should be supported by GIS based data collection and management system.

5.1. Mechanical sanitation

Palms that are not too deeply infested (terminal bud not infested when infestation starts by the canopy leaves bases, trunk not too deeply damaged by the larvae when infestation starts from the offshoots, aerial roots or petiole remains) can be sanitized either by insecticide injection or by mechanical sanitation. The purpose of mechanical sanitation is to eliminate the tissues where the larvae are, as well as to locate and destroy all the cocoons and adults. For tall ornamental palms (infestation is located in the canopy leaf bases), a precise and efficient protocol should be developed. For date palms, mechanical sanitation is practiced for many years, very simply with hand tools. When the detected symptom of infestation is the drying of leaves or offshoot, it is sometimes sufficient to remove and destroy the offshoot to sanitize the palm. When the larvae has passed from the offshoots to the trunk or when the infestation has started from the petiole remains, infested area must be eliminated with a sharp tool till reaching the healthy tissue. The infested tissue, if cut into small pieces does not need further treatment (the eggs and the larvae will die quickly in drying tissue). This simple mechanical sanitation presents two great advantages: it can easily be done by the farmer itself and no infested tissues are moved outside the infested area that avoids any risk of adult RPW spread. Furthermore, in case of slight and superficial damage, the tissue is removed from the palm and destroyed. Thereafter the wounded palm tissue is sprayed with a repellent insecticide or clay or gypsum paste to avoid attraction of females.

As, in some places, very complex protocol has often been recommended regarding the issue of wasted infested tissues, it would be perhaps desirable that very simple experimentation be implemented to demonstrate the absence of risk presented by larvae or eggs present in wastes cut into small pieces. Some new technologies have been proposed to sanitize infested palms but they don’t seem to present any advantage compared with the existing techniques.

5.2. Preventive insecticide applications (chemical/natural)

Preventive insecticide applications are currently either carried out through chemical or natural origin products. They have two purposes: (i) to kill the adults hidden at the bases of the leaves; and (ii) to protect the palms by killing adult female weevils and early stages of the pest.

Preventive insecticide applications must be applied either as by showering/soaking targeted zones of the palms or by injection (only for ornamental palms). To ensure the efficiency of the preventive insecticide treatments and minimize hazards on human health and the environment the following points should be respected:

- Preventive insecticide treatments should be applied only on the palms of the delimited infested area and during a limited period of time established according to the evolution of the traps captures.
- A range of insecticides should be tested and registered against RPW for each country.
- Attract and Kill products may be registered as a preventive semiochemical treatment
- There is a need for further testing of natural products against RPW.
- The dose and frequency of treatment for each registered pesticide against RPW to ensure proper use in the field operations.
- The following measures should be considered while taking up preventive insecticide applications.
  - In case of showers/soaking the pesticide solution should be targeted to the base of the leaves of the crown (ornamental palms of more than 2 meters) and inner leaf whorls, trunk up to 2 meters and offshoots (date palms and small ornamental palms).
  - For ornamental palms the option of attaching pipes to deliver showers of pesticides to the crown leaf bases requires periodic shifting.
  - For ornamental palms treatments by injection should not be considered as a routine technique as they create permanent wounds. They should be applied only for limited number of times and only in the frame work of program conceived and apply to obtain quick eradication of the pest. For date palm, injection should not be applied as for the moment no official data are available on the issue of insecticide residue content in the dates after injection.
- Pesticide residue studies should be done in palm tissues and especially in dates before registering any new pesticide for use in control program.

5.3. Curative insecticide treatments (chemical/natural)

- All relevant points mentioned under 5.1 should be applied.
- Need to develop a protocol for the rationale use of curative insecticide applications especially with regard to stem injection.
- Existing protocols of different countries should be reviewed and validated by specialists/experts in the field.
- Natural pesticides should be tested after details on the composition of the product are known.

5.4. Mass trapping

RPW pheromone traps capture only part of the weevil population in the field. Recently black colored traps have been reported to record superior weevil captures, while with regard to trap design, the dome shaped trap records significantly higher captures as compared to the traditional bucket trap. The synthetic kairomone (ethyl acetate) when added as a component to the RPW food baited pheromone trap is known to enhance weevil captures. Periodic replacement of the food bait and water, limits the need of increasing the number of pheromone traps in the field, besides significantly increasing the cost of an area-wide mass trapping program. In some countries mass trapping, could be taken up by lead/trained farmers. Numbering of every pheromone trap in the field is essential for systematic data collection and processing. This could be realized by geo-referencing the traps and use of the Radio Frequency Identification (RFID).

Service-less trapping options based on 'attract and kill' and use of a dry trap based on 'electro-magnetic radiation' have been found promising in Saudi Arabia as an additional component of the RPW-IPM mass trapping program. Further evaluation of attract and kill technology and the dry trap using electro-magnetic technology should be considered where ever it is not yet tested.

5.5. Biological control

For the moment, no biological control solutions have been successful when applied at a significant field scale and for a long period of time. For the preventive treatment of ornamental palms in urban environment where this type of solutions have been strongly encouraged, these solutions have been abandoned after few years because of the cost and the difficulty of application that represent implementing the treatment several times per year.

In general, the delivery systems for biological control agents (such as entomopathogenic fungi) should be tested under laboratory and field conditions. Experiments to harden these biological agents to resist arid environmental areas are an essential factor for their success in the field.

It is recommended to test agents already approved in EU and to test natural products that could enhance the palm resistance.

New technology is also available for improving the longevity of *Beauveria bassiana* to heat and UV light in the field.

5.6. Removal and disposal of highly infested palms

The measures adopted to process the severely infested palms are very variable. In some places, infested palms are cut and totally shredded. The last operation requires the use of huge machines that are available only in few places where the infested palms have to be transported. Shredding machine generate a very high temperature to kill all the stages of the insect (egg – larva – cocoon – adult). Such protocol that is very heavy, complex to be applied safely (to avoid RPW spreading) and expensive has been adopted only in few places. For some years, it has been proposed that the procedure to be adopted should be based on a risk analysis approach. Better knowledge of the RPW biology during these last years has allowed establishing a very important point to take into consideration in the risk analysis which is that the larvae are not *xylophagous* and die very quickly in drying tissue. As in some places, very complex protocol has often been recommended regarding the issue of infested tissues removed from the palm, where it would be perhaps desirable that a very simple experimentation be implemented to confirm the absence of risk presented by larvae or eggs present in these palm tissues that are cut in small pieces.

In ornamental palms, the risk analysis approach has led to distinguish between the infested and non-infested parts of the infested palms. In case of the former (infested palm parts), specific protocols of intervention have to be adopted. For the later (non-infested palm parts) different types of protocols are adopted depend on the equipment available and the local conditions. Such approach based on risk analysis and taking into consideration the local conditions remain to be developed for date palms. Very simple protocol that can be managed at the farm level with very simple equipment has to be proposed.

It is recommended to assess and dispose such palms at the site itself by exploring the possibility of onsite hand small pieces chopping, incineration with mobile incinerator, mechanical shredding with small/mobile shredders. Removal and the disposal of infested palms' procedures should be further refined and developed.

6. Data management/GIS/validation

A turnkey solution for a data collection system is desirable that consists of (a) geo-referencing palm trees using Google Earth Engine and remote sensing, (b) use of mobile phones for data entry and transmission and (c) use of GIS for data management and analysis. A custom app should be developed for Android and iOS smart phones that would allow users to record geo-referenced data at the field location on a standard form. Ideally, users should use their own smart phone in order to avoid the procurement, distribution and management of unique devices. The app would use the GSM mobile data service (GPRS) to transmit the data from the field to a centralized national RPW office in real time. A specific procedure would be developed to allow automatic importing of field data into a custom GIS that contains a spatial database at RPW offices. The GIS would be used for the management and analysis of field and smart trap data in order to prepare maps, tables, charts and reports, and take necessary management decisions. Open-source, non-proprietary software such as PostgreSQL/PostGIS database and QGIS are suggested for the spatial database and GIS respectively. In this way, annual licence fees are avoided, the GIS is platform independent (it can operate on Windows, Mac, Linux), and a large pool of available developers and expertise can be utilized to customize the GIS to RPW requirements. The primary base map for the GIS should be a geo-referenced map of palm trees (output from item (a) above). This base map in combination with regularly updated and historical field data can be utilized to assess the current situation of RPW, monitor its incidence and geographical spread, act as an early warning system, make well-informed decisions, and research historical trends in order to better manage RPW.

Automated data flow and a GIS will permit to elaborate various types of maps, tables and graphs at different time periods and spatial resolutions according to the type of requested information.

These analytical tools are indispensable for an effective multi-regional programme/strategy to combat RPW at all levels.

It is proposed that FAO Headquarters takes the lead in this topic, learning lessons and adopting the experience from the Canary Islands system. A training program for different categories of the users of the tools (mobile apps, GIS, software) should be developed.

Periodic validation of the control program based on weevil captures in traps, infestation reports and GIS generated spatial and temporal models is essential for effective management of the pest, besides judicious use of men and material.

7. Stakeholder participation and involvement in the RPW control programs

7.1. Farmer involvement

In most of the RPW infested countries, the farmers/stakeholders are not or very little involved in the RPW control programs. In many countries, all the activities are implemented by Governmental agencies. These programs are very costly and have not succeeded to eradicate the pest or even to avoid its spread. In some countries, the activities of the authorities are limited to supply the farmers with some insecticide.

The advantage of involving the farmers in the control program is considerable as they present in the farm and can assist in detecting infested palms in early stage of attack, an action that constitutes the key to control and eradicate the pest. Furthermore, all or most of the activities of an RPW control program could be perfectly realized by them at a very low cost if they are well trained.

The strategy will assist the countries to develop a clear-cut policy on farmers/stakeholder participation and engagement in RPW-IPM programs. Pilot projects to experiment and demonstrate the feasibility to involve farmers/stakeholders should be implemented. The encouragement of the farmer participation in the IPM program should be supported by:

- stakeholders mapping and needs analysis;
- implementing urgent studies, first, to dispose of a better knowledge of the socio-economic consequences of the RPW problem and of the farming systems in the infested areas, and, secondly, to propose adapted solutions to facilitate the farmers involvement;
- strengthening extension programs, activities, knowledge sharing mechanisms, communications, farmers' organizations etc. for farmers/stakeholders;
- improving the policies towards incentives to have a positive impact on a better marketing and incomes to farmers.

7.2. Role of cooperatives, NGOs and private sector

Government agencies working with RPW-IPM programs should establish defined linkages and coordination mechanism with cooperatives, NGOs and private sector to make the program more meaningful and effective. Involvement of oasis program in the RPW program in concerned countries is also recommended.

7.3. Institutional cooperation / networking

The national strategies should include a mechanism for strengthening the cooperation among institutions at the national level. Strong engagement and involvement of the law enforcement authorities and other stakeholder organizations is crucial for effective implementation of the phytosanitary measures and limiting the spread and risk of RPW.

8. Capacity building, communication and extension service

The RPW-IPM national strategies should include a capacity building programs, tailor made for different categories of stakeholders (farmers/workers and other stakeholders) involved in the implementation of IPM of RPW. The program should be enhanced by introduction of participatory approach (Farmers Field School) and demonstration fields for farmers and farm workers to empower them updated knowledge and field practices. One of the capacity building components should be the use of social media and mobile applications for knowledge and experience sharing. Periodic exchange of personnel to study and be exposed to on-going RPW-IPM program at the national level is vital for updating the knowledge and experience of the technical staff and farmers.

The regional RPW program will assist the countries in developing a capacity building programs and user friendly training materials with authentic, updated information in different languages to serve the needs of different categories of personnel and stakeholders.

One of the important components of the IPM program is the communication and extension service/program. Communication officers and extension agencies should be actively involved during the entire program to facilitate dissemination of information among all the stakeholders through different mass media. Use of social media to expedite transmission of information is essential to ensure the quick and wider outreach to all stakeholders and audience.

Different propagation tools and materials, such as short video messages, posters, bags and other gifts with easy and short messages to attract the attention and raise the awareness of different category of the public.

Extension agencies in each country or region can adopt some village or group of farmers and implement the RPW control program in its totality and showcase the benefits to other farmers. Such farms may be called model farms free of RPW where some field days could be organized to educate and demonstrate the technology to other farmer groups and regions.

There is a need to familiarize journalists to contribute to raising awareness. Social scientists and economists should be involved in the RPW management program.

9. Management and institutional set up

The national RPW control programs in most of the countries are operated by or under the supervision of the NPPOs of the Ministry of Agriculture (MoA). In some countries, there are standalone centers/programs mandated to control RPW under MoA, while in other countries the responsibility of controlling RPW is implemented by different institutions under the supervision of different ministries with very weak coordination. It is also observed that palms for ornamental gardening that often harbor the pest come under the overall mandate of the municipality. Furthermore, in most of the countries, palms owners and farmers are not involved or very little in RPW control programs.

These factors result in the weak management of the pest. The Governmental administrative and bureaucratic set up also often impedes the smooth functioning and timely implementation of the national RPW control program. In most of the countries the implementation of the national program is challenging due to the shortage of both human and financial resources, while in some countries the control program is either partially or fully outsourced to private companies with weak monitoring, evaluation and supervision.

Furthermore, the national RPW control programs have almost no linkages with research institutions/universities working on RPW as a result of which the research output usually does not address the practical needs in the field.

For efficient functioning and operation of the national RPW control programs the concerned Governments should make provisions to address the above gaps in the management and institutional set up and develop a framework for coordination between the national RPW control program and other relevant Governmental and non-Governmental institutions and farmers groups.

10. Monitoring and Evaluation

Currently most of the national RPW-IPM Programs lack the component of the Monitoring and Evaluation (M&E). This has an adverse impact on the success of the programs, sustaining the positive results achieved and judicious use of resources.

The national strategies should be based on the Strategic Planning/Results Based management approaches supported by a logical framework with clear key performance indicators and targets and M&E mechanism.

Monitoring is the systematic collection and analysis of information to track progress against set plans and targets, and check compliance to established standards. It helps identify trends and patterns, adapt strategies and inform decisions for the management of the program.

Evaluation involves identifying and reflecting upon the effects of what has been done, and judging the success. The findings of the evaluation will allow program managers, beneficiaries, partners, donors and other program stakeholders to learn from the experience and improve future interventions.

Monitoring and evaluation forms the basis for clear and accurate reporting on the results achieved by the national programs. Thereby, information reporting becomes an opportunity for critical analysis and organizational learning, informing decision-making and impact assessment of the programs. It is vital to involve key stakeholders as much as possible in the evaluation process.

In the context of the national RPW-IPM programs, it is recommended that a midterm and annual evaluation is carried out.

11. Research & Development

Recent references on RPW research are presented in Annex-1. The IPM national program should establish good cooperation with the research institutions and technology developers for sharing the information about the most recent results of research and innovations developed.

Different methods and technologies for the detection, surveillance and management of the RPW have been introduced in the recent years by the researchers and technology developers that have to be further evaluated and tested for their feasibility to be used in the field, as quick, user friendly and cost effective technologies.

The national RPW programs should include a component for testing and validation of recent innovative techniques and methods management of the RPW including trapping techniques, preventive and curative chemical treatments, quarantine protocols etc. that would facilitate the work and improve the effectiveness of the program.

II) Result matrix of the action plan

	Indicators	Targets	Time frame	Regional program/ expected contribution
Output 1	Phytosanitary (quarantine) measures effectively enforced			
Activity 1.1. Review of the national phytosanitary system in relation to RPW control	Phytosanitary systems reviewed	Strength/ gaps of the system are identified and communicated to FAO	July 2017	Support in the review and assessment of the systems
Activity 1.2. Review/update/ develop clear regulations for import requirements as well as phytosanitary measures to regulate the movement of palms within the country	Number of regulations are reviewed/ updated/ developed	Report on the regulations reviewed/ developed with their drafts reported to FAO	September 2017	FAO/IPPC could help in review/develop the regulations based on the ISPMs
Activity 1.3. Develop clear inspection and treatment protocols/ guidelines for offshoots and palms with procedures for strengthening quarantine inspection at borders and plant protection services	Number of protocols/ guidelines developed	Report on the protocols/ guidelines developed with their drafts reported to FAO	September 2017	The Regional Program could help in developing of the protocols/guidelines

	Indicators	Targets	Time frame	Regional program/ expected contribution
Activity 1.4. Develop guidelines for establishing commercial date palm nurseries and put in place a system for date palm nurseries' registration and certification	Number of guidelines for establishing commercial date palm nurseries and registration and certification system put in place	Country reports of the developed guidelines and registration and certification system put in place submitted to the FAO	January 2018	The Regional Program could help in developing of guidelines and registration and certification systems
Activity 1.5. Support the establishment of facilities for production of tissue culture palms	Number of facilities for production of tissue culture palms established in the countries	Reports from the countries about the progress in establishing the tissue culture facilities	Continuous activity	
Activity 1.6. Put in place a mechanism for strengthening the coordination and engagement of all law enforcement agencies and other stakeholders for enforcing of the phytosanitary regulations	Mechanism for strengthening the coordination and engagement of all law enforcement agencies is developed	The national RPW-IPM program is supported by clear mechanism for engagement all law enforcement agencies and other stakeholders	End of December 2017	

	Indicators	Targets	Time frame	Regional program/ expected contribution
Output 2	Early detection, surveillance and monitoring capabilities improved			
Activity 2.1. Develop a harmonized technical protocol for visual inspection, and involve farmers and other stakeholders in the process of early detection	Number of technical protocols for visual inspection developed by the countries	At least 3 protocols are developed by each country and submitted to regional program for review.	September 2017	The Regional Program could help in developing technical protocols for visual inspection
Activity 2.2. Assess and test new advanced technologies being developed for early detection	New advanced technologies tested/adopted by the countries	Report on the new technologies tested/adopted submitted by the countries	Continuous activity	
Activity 2.3. Develop a clear protocol/program for the surveillance and monitoring based on the International Standard for Phytosanitary Measures (ISPM 6), including guidance for surveyors and inputs/resources needed.	National surveillance and monitoring program developed by the countries	Repot on the surveillance and monitoring program developed based on the ISPM6	October 2017	FAO/IPPC could help in review/developing the surveillance and monitoring programs
Activity 2.4. Deploy a mobile application and GIS aided monitoring system for efficient mapping, data collection, analysis and management of the surveillance and monitoring program.	The mobile application and GIS is developed by FAO and made available to the countries	The mobile application and GIS is operational and used by member countries	March 2018	Secretariat of the Program with support of FAO-CIO will assist in developing the system and make it available for the countries

	Indicators	Targets	Time frame	Regional program/ expected contribution
Output 3	Preventive and control measures improved			
Activity 3.1. Prepare national guidelines for adopting good agronomic practices (palm density in the field, irrigation, crop and field sanitation etc.) for the management of RPW	Number of national guidelines for adopting good agronomic practices to control RPW developed	Report on guidelines for adopting good agronomic practices to control RPW submitted by member countries	October 2017	The Regional Program could assist member countries
Activity 3.2 Standardize national guidelines for preventive (sprays/showers/ stem injection) and curative (chemical & mechanical sanitization) treatments against RPW	Number of guidelines for preventive (sprays/ showers/stem injection) and curative (chemical & mechanical sanitization) developed by member countries	Report developed on guidelines for preventive (sprays/ showers/stem injection) and curative (chemical & mechanical sanitization)	October 2017	The Regional Program could assist member countries
Activity 3.3 Develop a list of registered pesticides for RPW that have undergone the national registration process	List of registered pesticides for RPW that have undergone the national registration process developed in each country	Annual reports on the list of registered pesticides for RPW that have undergone the national registration process	Annual activity	

	Indicators	Targets	Time frame	Regional program/ expected contribution
Activity 3.4. Identify national laboratories/ agencies to carry out and authenticate pesticide residue analysis in date and other palms	National laboratories/ agencies to carry out and authenticate pesticide residue analysis in date and other palms identified	Report on national laboratories/ agencies and results of pesticide residue analysis in date and other palms submitted by member countries	Annual activity	
Activity 3.5. Develop and standardize RPW pheromone trapping protocols with respect to trap design, trap density and servicing	Current status of RPW pheromone trapping protocols standardized	Report on the RPW pheromone trapping protocols submitted by countries	October 2017	
Activity 3.6. Test new RPW trapping technologies, including smart traps, geo-referencing the traps, use of the Radio Frequency Identification (RFID), and service-less options including 'attract & kill' and electro-magnetic traps	New RPW pheromone trapping technologies tested	Report on the new RPW pheromone trapping technologies tested is submitted by the countries	Continuous activity	
Activity 3.7. Develop and adopt a simple protocol for proper and safe removal of infested palms that can be managed at the farm level with simple equipment	A protocol for proper and safe removal of infested palms developed using simple techniques developed member countries	Report on the protocol for proper and safe removal of infested palms submitted by member countries	December 2017	

	Indicators	Targets	Time frame	Regional program/ expected contribution
Output 4	RPW-IPM program institutional capacity, planning and implementation enhanced			
Activity 4.1. Develop and adopt a 'participatory approach' plan for enhancing participation and engagement of the farmers/ stakeholders in the national RPW-IPM programs	A plan for enhancing participation and engagement of the farmers/ stakeholders in the national RPW-IPM programs developed by each country	Report on the participatory approach' plan in the national RPW-IPM programs received from each country	October 2017	
Activity 4.2. Establish a coordination, communication and networking mechanism with other national stakeholders (Governmental agencies, research & academic institutions, cooperatives, NGOs and private sector)	Coordination, communication and networking mechanism with other national stakeholders developed	Report on the coordination, communication and networking mechanism with other national stakeholders submitted by member countries	October 2017	
Activity 4.3. Develop a national capacity building program tailor made for the personnel working in the RPW-IPM program, farmers, law enforcement agencies and other stakeholders	A national tailor made capacity building program by member countries under the national RPW-IPM program developed	Capacity building programs are developed by member countries under their national program	Continuous activity	

	Indicators	Targets	Time frame	Regional program/ expected contribution
Activity 4.4. Develop user friendly training and awareness raising material including digital applications in a simple language of the targeted categories	User friendly training and awareness raising material developed by the countries	Need based user friendly training and awareness raising material to support the national RPW-IPM program developed by member countries	Continuous activity	
Activity 4.5. Develop pilot projects for the area-wide management of RPW that could be implemented in a farmer-participatory mode for oases communities utilizing the 'Farmer Field Schools' approach	Number of pilot projects for the area-wide management of RPW in farmer participatory mode developed by the countries	Report on pilot projects for the area-wide management of RPW implemented by the countries	Continuous activity	The Regional Program could assist member countries
Activity 4.6. Improve the RPW-IPM program planning and implementation by adopting a result based management approach (RBM) including efficient monitoring & evaluation with adequate allocation of resources and means	Number of RPW-IPM programs developed/ reviewed based on RBM approach	The national IPM strategies are developed based on RBM with M&E plans and reported to FAO	May 2018	The Regional Program could assist member countries in the review/ development of the programs based on RBM

B. Global and regional components

1. Global platform

A global Red Palm Weevil management platform will be established for the purpose of strengthening the coordination, information, experience and knowledge sharing at the global level. The global platform would:

- strengthen the coordination between member countries in early warning, information and knowledge sharing for effective management of RPW;
- promote environmentally safer RPW management tactics to minimize the risks of control operations on human health and environment;
- establish a repository of experts on RPW;
- facilitate the exchange of the research results, innovative technologies on monitoring, detection and management of Red Palm Weevil.

The Global Platform will be established with support of FAO, CIHEAM, IPPC and other partners and member countries, and could be hosted by FAO.

The platform will be open for partnership and cooperation with other stakeholders including regional and international organizations, research institutions, NGOs, private companies, etc.

A proposal for the establishment, operational scheme and contribution of members of the platform would be prepared by FAO and CIHEAM and shared will all countries and organizations for interest and contribution.

2. Regional program for Red Palm Weevil management in NENA Region

For the purpose of supporting the implementation of the proposed strategy, a Regional Program for Red Palm Weevil management will be established to create an enabling environment for cooperation and coordination, and assist the member countries of the NENA Region to improve their management strategies and programs of RPW management.
The Regional Program could be established and hosted by the FAO Regional Office for Near East and North Africa Region with support of CIHEAM, NEPPO and member countries.

The program would:

- strengthen the cooperation and coordination between member countries in early warning, information and knowledge sharing for effective management of RPW;

- assist in developing programs, guidelines and protocols for prevention, early detection, rapid intervention and management of the RPW and support the countries for their implementation;
- assist in developing approaches, strategies, methods, training tools to increase the involvement of the farmers in the RPW management;
- provide *ad hoc* capacity building programs and technical assistance to the national RPW management programs;
- support the member countries in preparing and implementing Monitoring and Evaluation (M&E) plans;
- develop GIS spatial database for data management and analysis with a mobile application for data collection and transmission that could be adopted by each country;
- support the countries in developing of harmonized phytosanitary measures and contingency planning approaches to eradicate RPW or to contain its spread;
- assist in building the human and institutional capacity of the national programs of member states;
- support and coordinate joint activities at regional level (joint surveys and management programs) and inter-regional level to foster cooperation and exchange of field experience among RPW national schemes/projects;
- promote environmentally safer RPW management tactics to minimize the risks of control operations on human health and environment;
- support studies on generating data on pesticide residues in fruits (dates, coconut etc.) and provide and share information on permissible limits for different classes of pesticides;
- support the research and development programs for promotion and validation of the innovative, safe and cost-effective technologies;
- establish a repository of experts on RPW;
- develop programs for resource mobilization to support the operation of the program.

2.1. Beneficiaries and stakeholders

The Regional RPW Program will facilitate and improve the cooperation and knowledge sharing between the member countries and provide technical assistance to member countries to improve their RPW-IPM programs.

The program will be open for partnership and cooperation with other stakeholders including farmer cooperatives, NGOs, private companies, research institutions etc. for promoting the national RPW-IPM strategies, and developing and validating of advanced management technologies. The gender issue will be considered in the strategy.

2.2. Operation of the Regional Program

- The Secretariat of regional program could be established and hosted by FAO.
- Member countries should identify a national focal point for the coordination, communication and for representing the country in the regional program.
- A trust fund account should be created by FAO for the financial contribution of the member countries and organizations to support the establishment, operation and activities of the regional program.
- The regional program should conduct an annual meeting of the member countries to;
  - assess yearly development of the RPW situation and the efficiency of the programs at the regional level;
  - develop the annual program for the regional program based on national and regional priorities.

2.3. Action plan of the regional program

	Time frame	Responsibility	Estimated Budget USD	
			One Time Cost (Non-recurring)	Recurrent Annual Operational Cost
Output 1	A regional RPW regional program is established			
Activity 1.1. Establishment and endorsement of the RPW regional program by the member countries	By end of June 2017	FAO, CIHEAM, NEPPO and Member countries		
Activity 1.2. Nomination of the Secretary of the RPW regional program and establishing of the secretariat	By end of June 2017	FAO, CIHEAM and NEPPO, Member Countries		Salary of the Secretary and Secretariat expenses
Activity 1.3. Nomination of national focal point and identification of the countries' contribution and commitments	By end of July 2017	Member countries		
Activity 1.4. Prepare the statutes of the regional RPW program	By end of July 2017	FAO, CIHEAM and NEPPO		
Activity 1.5. Create a trust fund account for the regional program	By end of July 2017	FAO and CIHEAM		
Activity 1.6. The first meeting of the RPW regional program to agree on the statutes, confirm the countries contribution and develop the annual program.	By end of September 2017	FAO, CIHEAM, and NEPPO Member countries	60, 000	

	Time frame	Responsibility	Estimated Budget USD	
			One Time Cost (Non-recurring)	Recurrent Annual Operational Cost
Output 2	The regional RPW program is fully operational			
Activity 2.1. Develop the three-year strategic framework for the program, and annual work plan program with clear performance indicators and targets.	By end of December 2017	- Secretariat of the program and national focal points of member countries - Clearance of FAO, CIHEAM and member countries	20,000	
Activity 2.2. Assist member countries in planning, implementing and validating of RPW national control programs	Continuous activity	Secretariat of the Program with support of specialized experts		50,000
Activity 2.3. Establish a RPW network with a data base for sharing information and knowledge.	By end of March 2018	Secretariat of the program with support of specialized FAO Divisions and CIHEAM	20,000	
Activity 2.4. - Develop and implement a methodology based on Google Earth, remote sensing and other technologies to geo-reference the location of palm tree plantations as the basis for mapping and monitoring infestations in a GIS - Develop a mobile application for data collection and transmission - Develop a GIS with a spatial database for data management and analysis	Within one year of stablishment of the program	Secretariat of the program with support of FAO-CIO	150,000	

	Time frame	Responsibility	Estimated Budget USD	
			One Time Cost (Non-recurring)	Recurrent Annual Operational Cost
Activity 2.5. Provide the countries with the technical assistance needed and capacity building programs	Continuous activity	Secretariat of the program with support of specialized experts and institutes		150,000
Activity 2.6. Prepare proposals for resource mobilization and follow up with donor agencies for funding	Continuous activity	Secretariat of the program with support of specialized experts		
Activity 2.7. Facilitate the coordination and communication with national, regional and international research institutions for validating and testing new technologies of RPW management.	Continuous activity	Secretariat of the program		
Activity 2.8. Assist the countries in preparing the technical resources on RPW management (regulations, guidelines and protocols)	Continuous activity	Secretariat of the program with support of specialized experts, FAO Divisions and external institutes		50,000
Activity 2.9. Develop and support implementation of a Monitoring & Evaluation plan for the evaluation of the national RPW programs	Annual activity	Secretariat of the program		10,000
Activity 2.10. Conduct annual meeting of the program	Annual activity	Secretariat of the program		50,000
Activity 2.11. Publish the annual report on the development of the RPW situation in member countries	Annual activity	Secretariat of the program		5,000
Total estimated budget without salaries of staff			**250,000**	**315,000**

C. Presentations of the Scientific Consultation

During the Scientific Consultation, the below mentioned 17 presentations were made on several aspects related to the management of RPW.

No.	Title / Author
1	The current global situation and challenges of RPW management programs *Romeno Faleiro*
2	The current global situation and challenges of RPW management programs *Polana Vidyasagar*
3	Management programs and challenges in RPW control in Near East and North Africa Region *Abdulrahman Al Dawood*
4	Management programs and challenges in RPW control in Asia and Pacific Region *Faridah Muhamad*
5	Management programs and challenges in RPW control in Europe *Khaled Djelouah*
6	Draft multi-disciplinary and multi-regional Strategy for Red Palm Weevil management (*Presentation of the RPW-IPM strategy for the Near East and North Africa*) *Shoki Al-Dobai and Michel Ferry*
7	The current state of the art research and technologies on RPW management *Hassan Al-Ayedh*
8	The Canary Island success story in eradicating red palm weevil *Moisés Fajardo*
9	Sustainability, application and delivery mechanism of biological control agents *Enrique Quesada-Moraga and Josep A Jaques-Miret*
10	Recent advances in insecticide treatments and application against RPW *Michel Ferry*
11	Overview of the early detection techniques and tools against RPW *Richard Mankin*
12	Overview of the early detection techniques and tools against RPW *Victoria Soroker*

No.	Title / Author
13	Use of GIS (Geographical Information System) for data management and analysis in A *Rhynchophorus ferrugineus* eradication program. *Moisés Fajardo*
14	Innovative solutions using modern technologies for better management, control and analysis of *Rhynchophorus ferrugineus* eradication *Keith Cressman/ Kiran Viparthi*
15	Advances in semiochemical mediated technologies against RPW *Romeno Faleiro*
16	Advances in semiochemical mediated technologies against RPW *Polana Vidyasagar*
17	Socio-economic studies and approaches for farmer involvement in the RPW control program *Slaheddine Abdedaiem, Noureddine Nasr & Michel Ferry*

Full presentations could be found and downloaded from the following link: http://www.fao.org/food-chain-crisis/how-we-work/plant-protection/red-palm-weevil/en/

D. List of presentations of the sides sessions

No.	Title / Author
	IPPC Session
1	Lessons learned from the management of RPW.
2	How implementing the IPPC standards contributes to effective management of RPW.
3	National and regional perspectives of RPW management in the Maghreb countries
	CIHAEM Session
1	The RPW as vector of bacteria, fungi and acari.
2	The RPW infestation elicit a control-factor repressive environment.
3	Host-plant species and management consequence over infestation, damage and control
4	Weevil larvae diet: histophagy vs plasmophagy.
5	Putative glandular traitorous associated with RPW ovipositor.
6	The role of Beauvaria bassiana on plant defence, Biocontrol and insect behavior modification.

Full presentations/abstracts could be found and downloaded from the following link: http://www.fao.org/food-chain-crisis/how-we-work/plant-protection/red-palm-weevil/en/

E. Abstracts / full technical papers of the presentation presented in the scientific Consultation

1. The current Global situation and challenges of RPW management program
by Jose Romaneo Falerio

2. The current Global situation and challenges of RPW management programs
by Polana S.P.V. Vidyasagar

3. An overview of Red Palm Weevil management in Near East and North African regions: Current status and future challlenges
by Abdulrahman S. Aldawood, Khawaja G. Rasool and Muhammad Tufail

1. The current global situation and challenges of RPW management programs

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Abstract

Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) is one of the world's major invasive pest species attacking around 40 palm species and has rapidly expanded its geographical range in the Near East and North Africa (NENA) region and the Mediterranean basin countries during the last three decades, posing a severe threat to date palm and the Canary Island palm. RPW has a significant socio-economic impact on the date palm production sector and livelihoods of farmers in affected countries, besides having devastating impact on the urban landscape.

Currently the pest is being managed by a pheromone based Integrated Pest Management (IPM) strategy where early detection of infested palms through periodic visual observations is crucial for its successful control. However, the cryptic/hidden nature of RPW makes it difficult to detect infested palms and calls for the development of an efficient and easy to use early detection device. Besides, mass trapping of adult weevils using pheromone traps, periodic inspection of palms to detect infestations, preventive and curative chemical treatments, adopting strict phytosanitary/quarantine regulations is also necessary to sustain control levels and prevent the spread of RPW through infested planting material. Efficient and timely

decision making is vital in achieving high levels of control/eradication of RPW as seen in the Canary Island RPW control program where the pest was eradicated. In this context collection, transmission and management of data generated on the major RPW-IPM parameters including weevil captures in traps, infestation reports and treatments applied etc. could be achieved by developing GIS based user friendly applications for use by farmers and other personnel involved in the control operations in the field.

Limited efficiency of the on-going management program resulting from weakness of human and financial potentials, absence of effective biological control agents, labor intensive control and high cost, lack of farmer's and stakeholder's cooperation are the other challenges facing the management practices.

Key words: *Rhynchophorus ferrugineus,* management, distribution, challenges

1. Introduction

Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) a key pest of palms, is a hidden and lethal tissue borer of date palm and other palm species worldwide. RPW has a significant socio-economic impact on the date palm production sector and livelihoods of farmers in affected countries, particularly in the Near East and North Africa (NENA) region which accounts for 90 percent of the global date production, besides having devastating impact on the urban landscape of several countries in the Mediterranean basin where it attacks the Canary Island palm. This lethal pest of palms was first described as pest on the coconut palm in 1906 (Lefroy, 1906), and date palm in 1917 (Brand, 1917). After gaining foot hold on date palm in the Middle-East RPW during the mid-1980s RPW has spread rapidly worldwide mainly through infested planting material transported for farming and ornamental gardening. The pest is currently managed using a pheromone (ferrugineol) based Integrated Pest Management (IPM) strategy.

2. Losses

There are few estimates on the losses incurred due to infestation by RPW. Direct losses due to RPW attack can be attributed to the value of the destroyed palms, the loss in yield and cost of implementing the control program. In the GCC countries, the annual loss due to removal of severely infested palms at 1 and 5% infestation has been estimated to range from $5.18 to $25.92 million, respectively (El-Sabea *et al.*, 2009). The pest also poses a threat to coconut and oil palm industry in

South and South-East Asia and severely impacts urban landscape in the EU and some countries in the Maghreb region of North Africa, where removal of infested canary island palms and also preventive and curative treatments run into several million dollars.

Furthermore, indirect losses may result from the restricted movement of trees, curtailing expansion of new plantations besides adversely impacting the environment and landscape as a result of chemical treatments and removal of the infested palms, respectively.

3. Biology, seasonality, host range and distribution

All life stages of the pest are concealed with the exception of part of the adult population. Adult female weevils lay about 250-350 creamy white eggs inside the palm tissue usually in cracks and crevices on the palm trunk. Palm volatiles emitted from fresh wounds on the palm often attract gravid female weevils for egg laying. Eggs hatch in 2 to 6 days while the larval stage lasts for 1 to 3 months with several larval instars. Subsequently, the pupal stage takes 15-30 days after which reddish-brown adults (35 mm long and 12 mm wide) emerge and can live on an average for up to 3 months. Adult male weevils have a tuff of bristles on the dorsal tip of the snout. (Wattanapongsiri, 1966; Avand Faghih 1996; Al-Dosary *et al.*, 2016). RPW population is highly aggregated in nature, due to which infestations often occur in clusters (Faleiro *et al.*, 2002, Massoud *et al.*, 2012).

Flight mill studies have shown that adults could potentially fly a distance of over 50Kms with a sizeable population being short distance fliers (<100m) with flight activity being predominantly diurnal (Ávalos *et al.*, 2014; Hoddle *et al.*, 2015). In the Middle East adult weevils are most active between March and May and again during October and November (Abraham *et al.*, 1998; Soroker *et al.*, 2005). Oviposition in RPW is strongly affected by temperature and less than one generation per year can be expected in areas with a mean annual temperature (MAT) below 15°C and more than two generations in those with MAT above 19°C (Dembilio and Jacas, 2012). Several overlapping generations of the pest may occur inside a single infested palm (Dembilio and Jacas, 2012), which may be due to the fact that part of the population is characterized by 'non-flyers' (Hoddle *et al.*, 2015).

After the mid-1980s, the host range of RPW has significantly increased from only four palm species in the mid-1950s Nirula (1956) to 40 palm species being currently reported (Anonymous, 2013; http://www.savealgarvepalms.com/en/weevil-facts/

host-palm-trees) among which the canary island palm, *Phoenix canariensis*, date palm, *P. dactylifera* and coconut palm, *Cocos nucifera* are the most widely preferred hosts (Faleiro *et al*., 2014). The expanded host range has also resulted in the rapid geographical expansion of the pest during the last three decades with RPW currently being reported from 46 countries. The Laguna Beach report of RPW during 2010 in California, USA has now been confirmed to be that of the closely related red striped palm weevil *R.vulneratus* (Rugman-Jones *et al*., 2013). The most recent report of RPW comes from Essex, UK during November, 2016 where it was detected in fan palms, *Livistonia rotundifolia* imported from an EU country.

(http://www.hortweek.com/first-red-palm-weevil-found-uk/plant-health/article/1415641).

4. Symptoms of damage and detection of infested palms

Infestation begins when gravid female weevils lay eggs into palm tissue that hatch into damage inflicting larvae which bore and tunnel the palm. Abraham *et al*., 1998 reported the following damage symptoms in date palm as *viz.* i) oozing of brownish fluid together with frass (palm tissue excreted by feeding grubs) which has a typical fermented odour, ii) drying of infested offshoots, iii) tunneling of palm tissue by grubs, iv) presence of adults and pupae at the base of fronds, v) pupae on the ground around an infested palm, vi) drying of outer leaves and fruit bunches and vii) toppling of the trunk in case of very severe and extensive tissue damage.

The hidden/cryptic nature of the pest makes detection of infested palms extremely difficult. Currently infested palms have to be detected through regular visual observations (at least bi-monthly) of individual palms in the susceptible age group of less than 20 years in case of coconut and date palm (Abraham *et al*., 1998). In the canary island palm, trees of all ages are attacked and infestation usually occurs in the crown, making detection even more difficult.

Acoustic detection, chemical detection, thermal and spectral imaging are some of the advanced early detection techniques being currently investigated (Mankin, 2011; Soroker *et al*., 2013). Specially trained sniffer dogs have been used to detected RPW infested palms and could be useful in phytosanitary inspections (Nakash and Kehat, 2000; Soroker *et al*., 2013).

5. Management

The management of RPW calls for a thorough understanding of the palm agro-ecosystem, especially in an area-wide control operation where besides technical competence, human resource capabilities and management backed by adequate financial support is vital. Upon detection of the pest, a pheromone (ferrugineol) based RPW-IPM strategy comprising of the following core components (i) regular inspection of palms to detect infestations, (ii) mass trapping adult weevils using food baited pheromone traps, (iii) preventive and curative chemical treatments and (iv) removal/eradication of severely infested palms is implemented. These IPM components are complemented by phytosanitary (quarantine) measures to ensure the movement of pest free planting material, adopting good agronomic practices specially related to palm density, irrigation method, crop and field sanitation, besides detection of hidden breeding sites, treating of fresh wounds, periodic validation of the IPM strategy, capacity building and extension activities.

5.1 Surveillance and monitoring

Prior to implementing the IPM strategy, surveillance and monitoring is essential to ascertain the presence of the pest. This is achieved by visual inspection of palms in the suspected area and also by setting food baited pheromone (monitor) traps along motor able roads to detect presence of adult weevils. The question pest managers often ask is 'if surveillance trapping programme needs to be carried out in areas where the pest does not exist'. To detect the presence of the pest early it would be advisable to implement a pheromone trap based monitoring programme at least once a year during peak weevil activity in areas where the pest does not exist but a threat is perceived.

5.2 Pheromone trapping

With the synthesis of the male produced RPW aggregation pheromone by Hallett *et al*., 1993, mass trapping of adult weevils using food baited pheromone traps (Four-window bucket trap: 5-10L capacity) is widely practiced (Faleiro, 2006; Vidyasagar *et al.*, 2000; Oehlschlager, 2016). Adopting the best trapping protocols (Hallett *et al*., 1999, Faleiro, 2006) with respect to trap design, food bait and lure, trap placement, servicing and density are essential to sustain the trapping efficiency (Hallett *et al*., 1999). Although RPW pheromone trap captures are female dominated, only a part of the adult population is captured by RPW pheromone traps and therefore trapping needs to be combined with other IPM tactics (El-Shafie and Faleiro, 2017).

Four-window bucket traps (5-10L) have been commonly used to trap RPW. Recently however, black coloured dome shaped trap (Picusan™) has been reported to capture more weevils as compared to the bucket traps (Vacas *et al*., 2013). Efficiency of the traps needs to be sustained by regular (bi-weekly) replacement of the food bait and water (trap servicing). In an area-wide operation with several hundred traps, this becomes tedious and expensive and restricts the enhancement of the trap density in areas with high weevil activity, there by compromising the efficiency of the IPM strategy. Soroker *et al*., 2015 identified several RPW host attractants *viz.* ethyl acetate, ethyl alcohol, ethyl propionate, pentan-1-ol, 2-methoxy-4-vinylphenol and gamma-nonanoic lactone. These are potential pheromone synergists that could be used to develop stand-alone RPW pheromone lures that may not need the support of natural food baits. Studies carried out in Saudi Arabia with service-less pheromone trapping options including 'attract and kill' (El-Shafie *et al*., 2011) and also the dry trap that operates on 'electro-magnetic radiation' have been found promising. Developing a smart dry trap would ensure automatic data collection and transmission that would be useful in decision making and validation of an area-wide control program.

5.3 Chemical treatments

There is a lack of protocols for carrying out preventive and curative insecticide applications. However, these treatments are commonly used to control RPW (Abraham *et al*., 1998; Faleiro, 2006; Ferry and Gomez, 2013; Dembilio *et al*., 2015). Regular preventive insecticide applications could often be excessive and unnecessary. Intensifying periodic inspection to detect infestations instead of periodic prophylactic sprays could help successfully control the pest. Plantations with high weevil activity as gauged from trap captures, removal of severely infested palms would warrant preventive insecticide applications. In the canary island palm where infestation usually occurs in the crown periodic preventive showers in the crown may be justified where the option of attaching pipes to the palm trunk to deliver showers of pesticides to the crown leaf bases could be practiced. Only limited number of stem injections in ornamental palms may be carried out while prohibiting stem injection on a preventive basis in palms grown as food crops (Ferry and Gomez, 2013).

Curative treatment to treat RPW infested palms is essential as this treatment (stem injection) if administered in the early stage of attack could prevent the palm from dying. Currently several pressure injecting systems are available. However, the long term impact of injecting insecticide solution into the palm under pressure is not known and should be carried out only under supervision of trained personnel. Instead, allowing insecticide solution to diffuse through 4-5 slanting holes (20cm deep) drilled around the infestation kills the feeding larvae and has been practiced successfully to treat palms in the early stage of attack. Studies on pesticide residue should be done in palm tissues and especially in dates and coconuts before registering any new pesticide for use in control program. In some countries, mechanical sanitization of the infested palm tissue is done to cure infested palms. Often this treatment is excessive resulting in much of the tissue being removed. Such palm (where tissue removal is excessive) wouldideally be required to be removed/eradicated

5.4 Agronomic practices

Agronomic practices influence the incidence and build of RPW in the field (Sallam *et al*., 2012) and also the efficiency of visual inspection and other treatments. In this context, role of offshoot management, frond pruning, irrigation method adopted, palm density (spacing) in the field, crop and field sanitation etc. need to be studied and adopted to reduce the risk of infestation and facilitate management of the pest. Although host plant resistance mechanisims involving antixenosis ans antibiotic effects are known (Farazmand, H. 2002, Dembilio *et al*., 2009, Barranco *et al*., 2000, Al-Ayedh, H. 2008; Faleiro *et al*.,2014) host plant resistance is not exploited for the management of RPW. Studies need to be carried out to incorporate these resistance factors in the traditionally cultivated varieties through classical plant breeding or advanced molecular techniques like RNAi.

5.5 Phytosanitory measures

Phytosanitory/quarantine laws exist in many RPW infested countries that prohibit the movement of infested planting material. However, implementation of the law is weak, resulting in spread of the pest in new areas, regions, countries and also re-inoculation of the RPW in areas where it is already under control. Also, lack of proper treatment protocol is currently inhibiting the implementation of phytosanitory measures.

5.6 Biological control

Although several biological control agents have been documented against RPW (Mazza *et al*., 2014) only entomopathogenic nematodes (EPN) (*Steinernema sp)* (Dembilio *et al*., 2010) and the entomopathogenic fungi (EPF), *Beauveria bassiana* (Guerri-Agulló *et al*., 2011) are currently promising in the field.

5.7 Monitoring and evaluation

Regular monitoring, evaluation and periodic validation of the RPW control program is essential for the judicious use of resources. In this context collection, transmission and management of data through automated data flow and a GIS will permit to develop spatial and temporal spread of the pest. GIS based spread sheets are used to assess the performance of area-wide RPW-IPM programs in the Al-Ahsa date palm oasis of Saudi Arabia (Massoud *et al*., 2011 & 2012). GIS was widely used in the Canary Island RPW control program where the pest was last reported in 2013 and officially declared as eradicated in 2016.

5.8 Stakeholder participation

Stakeholder participation and involvement in the RPW control programs, including farmer involvement, role of cooperatives, NGOs and private sector, institutional cooperation / networking, capacity building, communication, extension service and research and development are aspects that also need to be looked into for the successful management and eradication of RPW. In Mauritania strong involvement and participation of the farmers and other stakeholders in the control program have restricted the pest in its original foci in Tidjikja.

6. Conclusion

Despite some success stories in a few countries, RPW control programs currently being implemented have by and large not been successful in containing the spread or controlling the pest. The failures in the control programs can be attributed to difficulties in detecting infested palms early in the stage of attack, challenges and constraints facing application of quarantine measures, difficulties faced in delivering and sustaining biological control agents in the field and lack of awareness and commitment of farmers and other stakeholders in the control programs. The strategy supported with adequate resources, with systematic planning, good coordination and involvement of all stakeholders can lead to the eradication/ control of RPW as witnessed in the Canary Islands of Spain, and Mauritania.

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2. The current global situation and challenges of RPW management programs

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Abstract

The Red Palm Weevil *Rhynchophorus ferrugineous* L. (RPW) is a pest originating from the South Asia region, which has moved westwards to Middle East, North Africa and parts of Europe in the past three decades. Although use of an Integrated Pest Management (IPM) strategy through judicious combination of various control methods gave positive results in certain regions, these results could not be sustained and replicated elsewhere due to various factors. The cryptic nature of this pest makes the early detection very difficult and lack of awareness about methods of control and coordination among the stake holders about the pest are some of the other known reasons for its rapid spread and distribution throughout the NENA (Near East and North Africa) region.

Dependence on the conventional visual inspection method of palms to detect pest infestations is both laborious and time consuming. In recent years emphasis has been given on the development of devices for the early detection of the infestations in palms with bio-acoustic devices, X-rays machines, thermal image systems, etc. The alternate method of using trained sniffer dogs for the early detection of infestations in young palms and offshoots was standardized in certain private farms to some extent, to reduce the dependence on visual inspection by laborers. In early 1990’s the aggregation pheromone traps of red palm weevil were commercialized and were included in the IPM as an important component. There were excellent improvements in the lure dispensers, trap designs, trap density, besides the augmentation of trap catches through the addition of kairomones in various forms. However, the limited availability of human resources and transportation reduced the success rate of mass trapping and monitor trapping of weevil adults, as the traps needed periodic serving with replacement of fresh food bait and water. However, in recent times research was in progress to develop and introduce efficient, sustainable, dry traps.

The biological control methods using entomo-pathogenic nematodes and fungi in the Gulf countries were not successful due to high temperatures in summer months and inadequate delivery systems. A novel method of microencapsulation

technology has been developed for increasing the shelf life and tolerance to UV light of entomo-pathogenic fungus *Beauveria bassiana* and such technologies need to be explored in future for incorporation in the overall strategy of IPM. For long, the source and transport of planting materials have received very little attention from most authorities, resulting in spread of the RPW. A step in the right direction would be to establish certified nurseries for the supply of pest free planting material for new farms and gap filling purposes. The matrix of research, development and farmer participation for the overall subjugation of RPW in a viable and sustainable manner is presented.

3. An overview of Red Palm Weevil management in Near East and North African regions: Current status and future challenges

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Abstract

Date palm, *Phoenix dactylifera* L., is one of the most ancient cultivated tree on earth and is well recognized not only for its depiction as a symbol of cultural and religious heritage, but also for its huge contribution to the economy of Arabian Peninsula, especially Saudi Arabia. The Kingdom of Saudi Arabia is a home of over 23 million date palms and ranks third on the globe in quality date production. Unfortunately, this important fruit crop is under a regular threat of a highly invasive pest species, the red palm weevil (RPW), *Rhynchophorus ferrugineus* (Olivier). Since its detection in the Gulf Region during 1980s, this pest has been constantly spreading and reported from almost every palm growing country in the world. Rapid geographical spread of this devastating pest has challenged scientists to develop the most effective and efficient detection and management techniques to save this valuable natural resource. The published data on RPW management revealed that an effective RPW control could not be achieved by a sole dependence on any particular protection or control method. Case studies from various RPW affected countries have designated that integrated pest management (IPM) approach including: regular surveys, monitoring, cultural practices, mass trapping, phytosanitation, quarantine measures, and chemical application would be the best choice for the effective and efficient area wide control of RPW. For combating the RPW threat, we are working on integrated approaches including RPW DNA barcoding, development of a high throughput technology based on differential proteomic/transcriptomic analysis for early detection of RPW infestation, searching of the most-suited pesticides/bio-pesticides products and delivery techniques, and developing of RNAi-biotech-based control measures of the RPW using reproduction control genes, vitellogenin (Vg) and its receptor (VgR). Here the focus will be on the RPW current situation, challenges and overview of various control tactics being exercised in the Near East and North African Regions.

Keyword: Red palm weevil, *Rhynchophorus ferrugineus,* Near East, North African Region, current status, future challenges

1. Introduction

Red palm weevil (RPW), *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), is a crucial invasive pest species attacking nearly 40-palm species worldwide. The recent invasions of RPW around the sphere have become a global issue. This weevil was initially designated as a pest of coconut palms in northern India (Lefroy, 1906) and later was reported as a serious pest of date palms (Madan, 1917; Buxton, 1920). In the Gulf region, the RPW was first reported from United Arab Emirates (Zaid *et al*., 2002; Faleiro *et al*., 2012) while in Saudi Arabia it was reported in 1987 infesting an ornamental nursery in Al Qatif, the eastern province (Al-Abdulmohsin, 1987), and has recently been reported to invade almost all parts of the country. In the Gulf region, agro-climatic conditions, the distinct crop morphology and intensive modern farming system have greatly attributed to the ecological habitat fit for the RPW proliferation (Abraham *et al*., 1998). These favorable conditions and level of its high adaptability are the hallmarks typical for RPW invasion and geographical distribution. RPW was reported from Spain, Israel, and Jordan in 1994 and reached to Palestine in 1999, Italy in 2004, Canary Islands in 2005, whereas this weevil has been documented from Balearic Islands, France, and Greece in 2006, and Turkey in 2007 (Malumphy and Moran, 2007). Moreover, the RPW has also been reported from the Dutch Antillies and California, USA (USDA 2010, Ferry 2010). Based on detailed molecular studies the California RPW report has been now identified to be that of a closely related species *Rhynchophorus vulneratus* (Rugman-Jones *et al*., 2013). The Worldwide spread of RPW has been mainly because of the transportation/trade of the infested palms as planting material.

The female RPW lays eggs then hatched neonate larvae feed on soft palm tissues, chewing deep into palm trunk disrupting conducting channels leading to the death of palm tree (Fig 1). Based on our field experiments on infestation of palm trees, we have defined different levels of infestation starting from mild to medium and heavy using severity of RPW infestation as an indicator (Fig. 2). The RPW is a key pest of date palms having significant Socio-economic impact on date palm production and livelihood of farmers. The Food and Agriculture Organization (FAO) has declared RPW as a category-1 pest of date palm in the Middle East. In Gulf region, the annual losses by RPW, at 1 and 5% infestation level, have been estimated to be \$5.18 to \$25.92 million million USD during the year 2009 (FAO, 2017) while, in Muria, Spain, an amount of 7 million Euros was spent on RPW management programs. Moreover, in Valencia, a total destruction of around 20,000 palm trees by RPW during the years 2004-2009 has instigated a loss of about 16 million Euros.

In Near East and North African (NENA) region, the RPW has been reported from almost every country. In this region, around 0.95 million ha are under date palm cultivation, where 48 million palms are under the age of 20 years which is considered to be the most susceptible age group to RPW infestation. Challenges in RPW control include: inadequate and poor execution of quarantine protocols, non-existence of any structured IPM program, absence of active involvement of farmers and lack of their trainings on RPW issue and its management, presence of wild/neglected palm orchards - a critical source of RPW infestation, no success in early detection of RPW infestation, inadequate farming systems, and lack of skilled manpower and financial resources.

Figure 3. Red palm weevil caused damage to date palm

2. Management of RPW in NENA region

Currently, the major tactics promoted for RPW management in the NENA region include: quarantine regulations, monitoring of palm orchards for early detection of RPW infestation, mass pheromone trapping, and insecticide applications (Table 1).

2.1. Quarantine regulations

Although, the quarantine regulations, both international and domestic, do exist in the NENA region to prevent the transportation of infested palms/planting material, their enforcement is still poorly implemented. Farmer's awareness and cooperation, lack of trained staff, transportation through alternate routes, dearth of certified palm nurseries, and lack of coordination among law enforcement agencies are some of the challenges in the proper implementation of quarantine regulations.

2.2. Surveillance and monitoring

In NENA region, the visual inspection and pheromone trapping are the major techniques used currently for the surveillance and monitoring of RPW. Both techniques have some limitations including lack of funds, trained manpower, and farmer's confusion that pheromone traps attract RPW to their healthy orchards. Moreover, the poorly maintained and neglected old orchards, and date palm plantations in parks are not under the surveillance programs which sometime act as a source of secondary infestation. Surveillance program can be improved through frequent visual inspection and use of optimum trapping density, and implementing GIS based monitoring system for efficient mapping, data collection, analysis, and management of the surveillance and monitoring program (FAO, 2017).

Figure 4. Categorization of RPW Infestation Levels in date palm

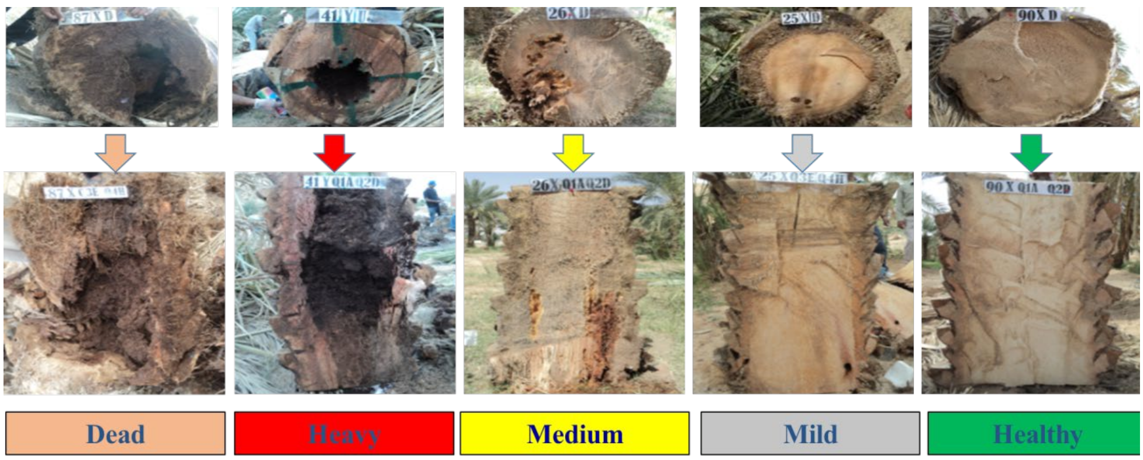

Table 1. Current status of the red palm weevil (RPW) and its management strategies in the NENA Region.

Countries	RPW First reported	Current Situation	Implementation of Plant quarantine	Infested palm species	Level of farmers awareness	RPW-infestation Detection method	Offshoots sources	Control strategies being deployed	Suggestions for RPW management
Saudi Arabia	1987	Moderate to severe	Yes	Date palms, Washingtonia palms	Limited	Visual/ Manual Pheromone traps	Tissue culture/ certified offshoots	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments.	Strict quarantine, IPM, Farmers awareness/ involvement, more trained technicians.
Qatar	1989	Moderate	Yes	Date palms, Washingtonia palms	Limited	Visual/ Manual Pheromone traps	Local/ imported	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments.	Strict quarantine, IPM, Farmers awareness/ involvement, more trained technicians.
Oman	1993	Moderate	Yes	Date palms	Limited	Visual/ Manual, Pheromone traps	Tissue culture/ local offshoots	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments.	Strict quarantine. Early detection, Use of natural enemies.
Morocco	2008	Moderate	Yes	Washingtonia and Canary palms	Limited	Visual/ Manual, Pheromone traps	Tissue culture/ certified Nurseries	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments, fumigation	Strict quarantine. Early detection, Preventive measures, Farmers awareness/ involvement. More trained technicians.

Countries	RPW First reported	Current Situation	Implementation of Plant quarantine	Infested palm species	Level of farmers awareness	RPW-infestation Detection method	Offshoots sources	Control strategies being deployed	Suggestions for RPW management
Egypt	1992	Moderate to severe	Yes	Date palms, ornamental palms	Limited	Visual/ Manual, Pheromone traps, DNA sensors	Tissue culture, local offshoots	Quarantine removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments, fumigation	Strict quarantine. Early detection, Preventive measures, Farmers awareness/ involvement. More trained technicians.
Iran	1990	Moderate	Yes	Date palms, ornamental palms	Aware	Visual/ Manual, Pheromone traps	Local offshoots	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments, fumigation	Strict quarantine. Early detection, Preventive measures, Farmers awareness/ involvement. More trained technicians.
Palestine	1999	Moderate to severe	Yes	Date palms, Washingtonia and Canary palms	Aware	Visual/ Manual, Pheromone traps	Local offshoots	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments, fumigation	Regional cooperation. Strict quarantine. Early detection. More trained technicians.
Iraq	2015	Moderate	Yes	Date palms, ornamental palms	Aware	Visual/ Manual, Pheromone traps	Tissue culture, Local offshoots	Quarantine, removal of heavy infested palms trees, Pheromone mass trapping, pesticide spay and injections as preventive and curative treatments.	Early detection, More trained technicians. Limited funds, Limited control methods
Libya	2009	Not known	Yes	Date palms	Limited	Visual/ Manual, Pheromone traps	Local offshoots	Pheromone mass trapping, pesticide spay and injections	Early detection, More trained technicians. Limited funds.

Source, FAO Country reports 2016

2.3. Early detection

Unfortunately, visible symptoms of RPW infestations appear at later stages after severe tissue damage, where it is too late to recover the palm tree. Thus, delay in the detection of RPW infestation is the main obstacle in its effective control. Several nondestructive methodologies were established and implemented for the early detection of insect pest with cryptic feeding behaviors (Mankin and Fisher, 2002; Mankin *et al*., 2002; Lemaster *et al*., 1997; Hagstrum *et al*., 1996; Shuman *et al*., 1993). Although some techniques; like visual inspections, acoustic sensors (Potamitis *et al.,* 2009), sniffer dogs (Nakash *et al*., 2000), and pheromone traps (Faleiro and Kumar, 2008); are currently being used for early detection of RPW in the NENA region, however each methodology has its limitations.

Strong efforts to develop a quick and reliable technique for early detection of RPW are ongoing. Currently work is done on differential proteomic (Rasool *et al.,* 2014; Rasool *et al.,* 2015) and genomics to screen some potential molecular biomarker, beside exploring other devices including: Near infrared spectroscopy (NIRS), Laser induced breakdown spectroscopy (LIBS) (Farooq *et al.* 2015), cameras (digital camera and thermal camera), and radars (radar 2000 MHz, radar 900 MHz) (Rasool *et al*., unpublished data). Acoustic detection, chemical detection, thermal and spectral imaging are some of the other advanced early detection techniques being currently investigated (Mankin, 2011; Soroker *et al*., 2013).

3. Control strategies

In date palm orchards, the important cultural practices that influence RPW infestation include: plant density, irrigation systems, palm and field sanitation, fronds and offshoot removal, and growing resistant varieties, etc. Recommended cultural practice can limit RPW infestation if implemented properly.

Moreover, regular date palm inspection, mass pheromone trapping, insecticides application through injection and spray, and limited use of biological agents such as entomopathogenic nematodes (EPNs) and fungi are some of the main preventive/curative techniques used for the control of RPW in NENA region. However, an effective and efficient control method for the management of RPW is still awaited.

RPW male produced aggregation pheromone 4-methyl-5-nonanol (ferrugineol) is widely used for the monitoring as well as mass trapping of RPW (Hallet *et al*., 1993, Faleiro 2006). Another compound 4-methyl-5-nonanone (ferrugineone) when added to ferrugineol was reported to significantly enhance the efficiency of pheromone trap when used in combination with ferrugineol (Abozuhairah *et al*., 1996). For best results, the pheromone traps are needed to be examined regularly including collection of the weevils, cleaning of the traps, renewal of the food bait and replacement of the exhausted pheromone.

The EPNs have been widely explored as bio-control agent mainly because of their broad host range, easy mass production, easy application, easy storage, and safety to non-target organisms (Kaya and Gaugler, 1993). The EPNs parasitically reside inside the infected host, therefore, known as endoparasites. They infect a variety of insects ranging from moths, butterflies, flies, beetles, grasshoppers, and crickets and have been found on both adult and immature stages. The EPNs belonging to families Steinernematidae and Heterorhabditidae are the most frequently studied groups against economical insect pests of different field and fruit crops. The previous studies have revealed that EPNs are the promising biocontrol agents of several insect pests including RPW. The application of *Steinernema carpocapsae* (Weiser) was reported to be effective as preventive and curative treatments against RPW under semi-field conditions (Llácer *et al*. 2009).

Locally collected, 3-isolates of EPNs belonging to the genus *Steinernema* were tested against 2nd, 6th, and 12th instar larvae, and adults of RPW under both laboratory and field conditions. Mortality percentage was recorded to be 100% in 2nd larval instar and adults stages whereas, 92-100 and 78-90% mortalities were observed in the 6th and 12th instar larvae, respectively (Alheji *et al.* 2009).

Moreover, entomopathogenic fungi have been successfully applied against several insect pests belonging to different orders. Entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*) have revealed good pathogenicity against RPW under laboratory conditions. Fungus penetrates into the RPW body, germinate there, and hijack the immune system of the host resulting into the death of the RPW. The dead RPW may cause horizontal transmission to healthy RPW. Therefore, RPW can be infected either by direct contact with spores or horizontal transmission from infected dead RPW individual (Lacey *et al.* 1999; Neves *et al.* 2001). The information published on *Beauveria bassiana* and *Metarhizium anisopliae* has revealed that entomopathogenic fungi are a promising candidate to be evaluated against RPW.

Insecticide application is the most commonly used and effective method for the control of RPW. Registered insecticides are used as preventive and curative treatment of date palm trees against RPW. As a preventive measure, the date palm trees are regularly sprayed with high powered sprayers and insecticides are applied slowly through central leaves to give a thorough coverage to the entire tree. The preventive treatments are repeated after every three months especially during RPW peak activity periods (April-June and September-November) of the year. As a curative treatment, the insecticides are applied both as spray (shower) and stem injection. For stem injections, points are marked around the palm trunk, either in spiral manners or at the base of the trunk depending on the insecticide use and infestation pattern, to drill holes at 30-45° using drill machine equipped with a brad point drill-bit (diameter, 8 mm). A biodegradable micro-injection plug is provided into the drilled hole to act as a barrier for restricting any backflow of the insecticide. The insecticide is delivered into the trunk immediately after drilling using various delivery systems including: the tree micro injection gun, the passive method (Gallon), low pressured (Balloon), and injection machines. Treated date palm trees are examined regularly to evaluate the efficacy of the treatment. Imidacloprid 20% SL, Chlorpyrifos 48% EC, Thiamethoxam 25% WG, Abamectin 1, 8% EC, Emamectin benzoate 4% ME, Lamda-cyhalothrin 2, 5% EC, and BioWeevil (a mix of oils) are the most commonly used insecticides in the region against RPW.

A distinct date palm dissection protocol was devised to determine the field efficacy of any pesticide applied to date palm trees against RPW. According to this protocol, the insecticide is applied through spray or injection or by both ways and then after a specific period the treated palm tree is cut down from the base, which is then logitudenally cut into smaller logs each of one meter length (Fig. 3). Each log is further cut into two longitudinal halves and then into four quraters for more detailed internal obserations. Each quarter is first observed from the inner sides (A and B), then peripheral side in addition to the top and base of each log to identify any sign of RPW infestation (galleries) and for the collection of live and dead RPW individuals. Results obtained through this procedure for a prevoius experement is been presented as an example (Table 2).

To impede the RPW risk, we are focusing on integrated approaches including RPW DNA barcoding (Sukirno *et al.* 2017a; Sukirno *et al.* 2017b; Sukirno *et al.* 2017c), development of a high technology based on differential proteomic/transcriptomic analyses for early detection of RPW infestation, searching of the most-suited pesticides/biopesticides delivery techniques, and developing of RNAi-biotech-based control measures of the RPW using reproduction control genes, vitellogenin (Vg) and its receptor (VgR). Our recent findings on RNAi-based Vg gene silencing demonstrate that Vg gene has the potential to stop the RPW reproduction that would ultimately lead to develop the novel strategies for RPW management.

Figure 5. Dissection procedure of date palm tree for detailed observation of RPW infestation and data collection.

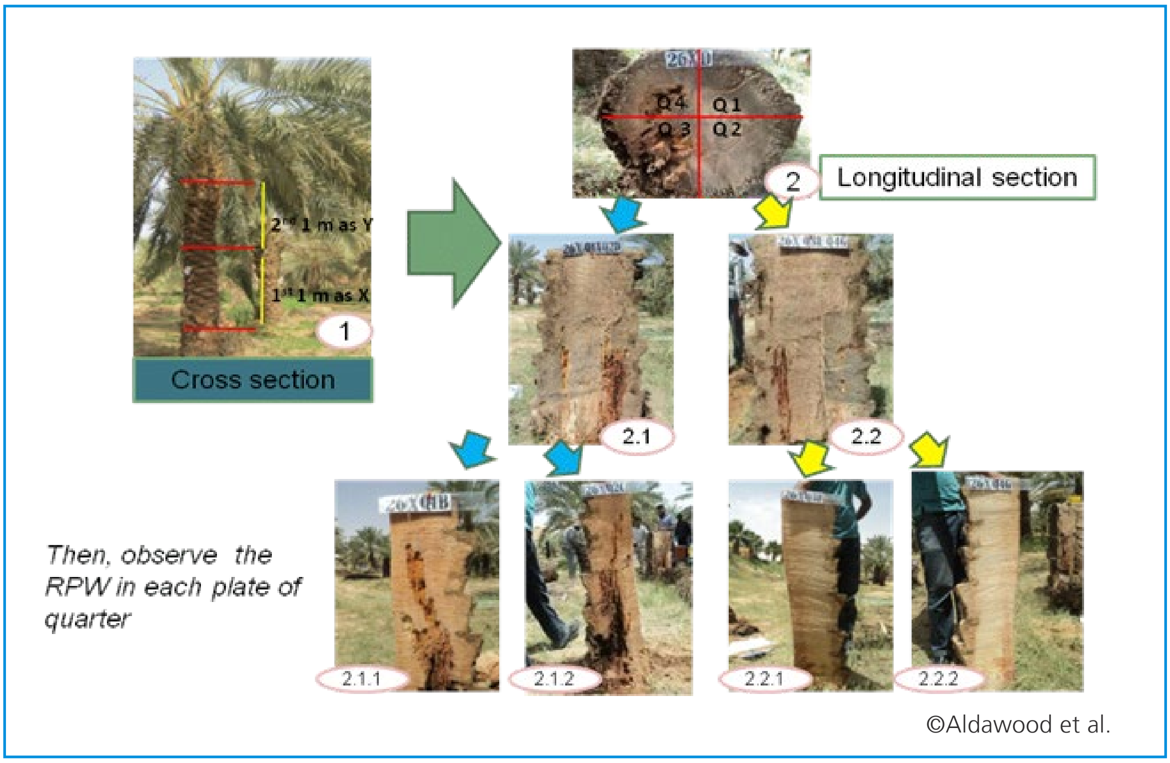

Table 2. Results obtained through the devised date palm dissection protocol after application of different chemical control programs on palm trees against red palm weevil at Alwaseel farm Riyadh, Saudi Arabia.

Treatments	Machines used	No of date palm trees dissected	Mortality percentage of different RPW stages			Average mortality %
			Larva	Pupae	Adult	
Red palm weevil control program -1	Italian	11	62.25 ± 14.4ab	93.33 ± 66.67a	85.87 ± 6.74a	79.70 ± 6.43ab
	Saudi	3	90.91 ± 9.09a	100a	60 ± 4.00a	85.59 ± 14.41ab
	Spray	4	50.61 ± 25.53abc	100a	86.59 ± 6.22a	80.72 ± 9.56ab
Red palm weevil control program -2	Italian	9	100a	100a	85.19 ± 11.26a	94.71 ± 3.84a
	Saudi	4	100a	-------	98.53 ± 1.47a	89.07 ± 9.26a
	Spray	12	37.34 ± 15.11bc	-------	71.34 ± 10a	55.61 ± 11.04b
Control	Italian	6	13.32 ± 6.36bc	0b	20.09 ± 11.65b	18.31 ± 4.69c
	Saudi	2	0c	-------	-------	0c

4. Recommendations

Based on our understanding and knowledge here are some suggestions for successful management of the RPW:

1. Promote awareness among farmers and related stakeholders about the significance of the RPW issue.
2. Develop a protocol for visual inspection of RPW infestation in a language easily understood for the farmers and other supporting staff.
3. Develop a quick/reliable, cost effective, and easily applicable early detection device or technique for RPW infestation.
4. Risk assessment initiative of the area adopting both visual observation and pheromone traps.
5. Develop good agronomic practices that limit RPW attack.
6. Develop a follow up plan for preventive measures including waste treatment and sanitation, wounds treatment, removal of neglected orchards, pheromone trapping, and insecticide applications via spray and injection.
7. Explore the potential of indigenous biocontrol agents (nematodes, fungi and virus etc) and identify an efficient delivery system for their application against RPW.
8. Develop a RPW-IPM program and train farmers/stakeholder for participatory RPW management.
9. Encourage the establishment of tissue culture laboratories for the production and supply of RPW free planting material.
10. Train Plant Quarantine Staff and other law enforcement authorities on the RPW issue.
11. Develop a protocol for the rationale use of preventive insecticide applications.
12. Use of preventive insecticide treatments based on infestation foci and trap capture data.
13. Test a range of insecticides and register them against RPW.
14. Carry out trials on residue analysis before authorizing injection for preventive treatments in date palms,
15. Develop removal and the disposal procedures of infested palms.
16. Assess and dispose of infested palms in the site itself.
17. Explore the possibility of onsite incineration/small shredders of the removed palms through mobile incinerating trucks/mobile shredding machines.
18. Strengthen extension programs, activities, knowledge sharing mechanisms, communications, and farmers' organizations.

19. Establish defined coordination mechanisms with non-governmental organizations (NGO's), private sector, and cooperatives to make the program more effective.
20. Introduce participatory approach (Farmers Field School) for farmers and farm workers to empower them with knowledge and field practices.
21. Strengthen cooperation among institutions at the national level and initiate programs of cooperation at the regional and international level.
22. Use of social media to expedite transmission of the information

5. Future **Plans**

1. Develop and examine new integrated pest management (IPM) strategies including biological, chemical, and biotechnological techniques for effective and efficient control of RPW in orchards and urban palms.
2. Assess the RPW detection technologies including, acoustic detection and X-ray digital analysis, Laser-induced breakdown spectroscopy (LIBS), and Near Infrared Spectroscopy (NIRS) in terms of their economic and logistic viability.
3. Devise a quick and reliable potential molecular biomarker through modern differential proteomics and genomic techniques for the early detection of RPW infestation.

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4. Management programmes and challenges in Red Palm Weevil (RPW) control in the Asia Pacific Region

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Abstract

The red palm weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) is a devastating pest of palms and is reported to attack more than dozen palm species worldwide. The weevil was found in India as early as 1891, however it was only in 1906 that it was recognized as a deadly insect pest in coconut palms. RPW has been found in many countries in Asia-Pacific region such as India (1891), China (1998), Malaysia (2005), Thailand, Indonesia, Philippines, Vietnam, Japan and others.

Although the weevil was first reported on coconut *Cocos nucifera* from South Asia, during the last two decades it has gained a foothold on date palms *Phoenix dactylifera* in several Middle Eastern countries from where it has moved to Africa and Europe, mainly due to the movement of infested planting materials. In the Mediterranean region, RPW also severely damages *Phoenix canariensis.* Currently, the pest is reported in 15% of the coconut-growing countries and in nearly 50% of the date palm-growing countries.

Integrated pest management (IPM) strategy has been employed in several countries (India, Malaysia) to manage the RPW. At present, use of food baited pheromone traps in both surveillance and mass trapping programmes form a key component of the IPM strategy against RPW. Early detection of infestation in the field is important for the success of any RPW-IPM programme. Quarantine system is also in place to control the movement of the planting material from the infested country. Strict pre- and post-entry quarantine regimes is essential to make sure only pest-free and certified planting material can be transported. Insecticide is also being used to control the RPW by applying through trunk injection and soil drenching.

Training must be provided for the quarantine officers to ensure that they recognize the RPW as well as the symptoms of infestation as they are the key persons to confiscate and destroy the infested planting material before it enters the country. Public awareness is also another important tool to engage the public to share their responsibility by not bringing into the country planting materials from the infested country.

It is very challenging to manage the RPW once it is established in the area. Commitment from individual governments is very crucial to ensure the success of the control and eradication programs. The IPM programme can be strengthened by intensifying the search for effective natural enemies, breeding of tolerant or resistant palm varieties to the pest, development of biocontrol techniques and fabrication of a RPW infestation detector.

5. Management programs and challengs in RPW control in Europe

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Abstract

The Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier, 1790), has become a pest of cultivated palms for a relatively long time (Milne, 1918; Simmonds, 1925; Faleiro, 2006). The RPW host plant moved from coconut to alternative host date palm and Canary palm thereby causing severe damages by killing thousands of *Phoenix dactylifera* L. and *P. canariensis* in the EU-Mediterranean area. The RPW is now considered a quarantine pest by EPPO and regulated in member countries as a pest of limited distribution (A2 pest).

Following its first outbreak in Spain (1996) and despite the efforts and resources provided by the National and EU plant protection organizations (PPO), the RPW has been invading the EU countries where palms are cultivated. Most of the infested plants belong to *P. canariensis* Hort., the main ornamental palm on the EU-Mediterranean coast.

The ability of RPW to spread and the lethal interactions with its host plants turn the weevil into a serious pest for economically relevant palms in the southern EU countries. Canary Islands PPO was the only one able to eradicate the pest and the last foci were declared free from RPW in May 2016.

The other EU-Infested countries experimented various preventive and curative control actions, based on traditional and innovative technologies; however, no curative control means has been found to be fully effective. In this context, the cut down and disposal of symptomatic palms was suggested to minimize the side effects of severe infestations. Unfortunately, this suggested action was not effective, considering that the RPW adults disperse before the evidence of the infestations.

Additionally, the difficulties in RPW-infested plant early detection with the weak quarantine procedures and the inefficient awareness programs, contributed to rapid dispersion of the weevil and the infestation pressure resulted in scarce infestations of other ornamental species.

Looking at RPW control experience in the old continent, it seems reasonable that an effective RPW control strategy shall originate from preventive and protective actions. Pest control will engage all the stakeholders by integrating effective control means into a shared Integrated Pest Management (IPM).

The strategy will target the pest, by strengthening the phytosanitary measures, considering the key-point analysis in the weevil life-table, evaluating the pest population density and dynamic, the host plant density and the RPW ability to induce a protective environment.

6. Proposed multi-disciplinary and multi-regional strategy for the management of Red Palm Weevil

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Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) is a key pest of palms originating from South and South East Asian Countries that has significantly expanded its geographical and host range during the last three decades. In the Near East and North Africa Region, RPW is causing wide spread damage to date palm *Phoenix dactylifera* L. and having both economic impacts on date production and environmental impacts. It is also present on Canary Island palm *P. canariensis* in few cities of Morocco and Tunisia presenting a serious threat to the southern oasis. RPW has been spreading globally and has not been effectively managed in spite of several efforts and resources provided by countries and organizations. Extensive research has also been conducted on the management of RPW. Weak implementation of quarantine procedures, difficulties in the early detection of RPW-infested plant materials and insufficient involvement of the farmers have contributed to its rapid spread.

The proposed strategy was developed based on the analysis of the current management programs of RPW in different countries and identified challenges and weaknesses. The proposed strategy aims to support efforts/programs of countries to contain the spread and eradicate the pest, and create a framework for cooperation and coordination of efforts at the regional and inter-regional level for supporting the integrated and sustainable management programs to control RPW; and to reduce its devastating effects on the environment and food security, and socio-economic impact on rural communities.

The proposed Multi-disciplinary and Multi-regional strategy for the management of Red Palm Weevil was developed by a team of FAO, CIHEAM, IPPC, NEPPO and other international experts.

The presentation will present both components of the strategy; the national component that aims at improving the ongoing national programs for the effective management of RPW at country level and the regional component of the strategy that aims at creating an enabling environment for cooperation and coordination for improvement of the RPW management strategy at the regional and inter-regional level through establishment of a regional RPW platform/program with support of FAO and other specialized international and regional organizations.

(See the Framework Strategy)

7. The current state of the art research and technologies on RPW management

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Abstract

Date palm is the major crop of agriculture sector in Arabian Peninsula, cultivated for than five thousand years *Phoenix dactylifera*. However, for the last three decades *Rhynchophorus ferrugineus* has caused significant annual production losses. Red palm weevil (RPW) *Rhynchophorus ferrugineus* is a major pest of palm species globally and is known to cause heavy damages annually in different places in the world such as Far-east and Middle eastern countries. Initially after emerging from south Asia this pest flourished in the Middle eastern countries where it causes annual loss of millions of dollars where significant percent of date palm production is lost because of this pest. In the Gulf region, the number of

date palm trees have been estimated to be 109 million yielding with 4.2 million metric tons. The RPW attacks different palm species including *Phoenix dactylifera, Areca catechu,* and about 15 more. Since very beginning of its emergence in local date palm orchards, this pest has been mainly controlled by the use of synthetic insecticides.

In order to control RPW, number of research studies have been carried out in different fields. However, bibliographic data reveals that to manage this pest, a few aspects received more focus as compared to others. Generally, more work has been done post-emergence of this pest where control measures including insecticides, pheromone traps and biological control measures to avoid expanding of this pest, but the angles that have been neglected include early detection of this pest, molecular studies, cellular studies etc.

In this study we tried to estimate, how the world's research community is responding to counter the pressure of this notorious pest. During this study, assessment was made on how much focus has been given on certain research angles and the points that have been neglected and need further work.

The overview of the work on RPW reveals that there was a lot of repetition and redundancy of the work. There are a number of areas that were heavily worked on. However, I think it is necessary to concentrate on some areas that are needed and minimize the work on others. Therefore, the research priorities should be given to early detection and forecasting, insecticides delivery techniques, systemic insecticides, insect plant tritrophic relationship and applied molecular cell studies.

8. The Canary Islands success story in eradicating Red Palm Weevil

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Abstract

After the first detection in 2005 of *Rhynchophorus ferrugineus* in the Canary Islands, the government implemented the Red Palm Weevil (RPW) regional eradication program.The application of different measures in a coordinated and integrated

way for 10 years has resulted in the total eradication of this pest in the archipelago. In May 2016 the last affected area located at the island of Fuerteventura was declared free of pest.

The different groups of measures applied and the manner in which they were executed are discussed. Special emphasis is placed on the factors considered key to success.

It is concluded that, in certain circumstances, with the knowledge and techniques available the eradication of RPW is possible.

Key words: *Rhynchophorus ferrugineus,* Red Palm Weevil, eradication program, Canary Islands.

1.Introduction

The Canary palm, *Phoenix canariensis* Hort. Ex Chabaud, endemic to the Canary Islands, is one of the most representative elements of biodiversity in the Canary landscape.

In the 2000 decade, the real estate boom originates the increase of the import of large number palm trees, especially *Phoenix dactylifera* L. This resulted in the entry of RPW in the Canary Islands, posing a serious threat to the conservation of the *Phoenix canariensis* of the islands.

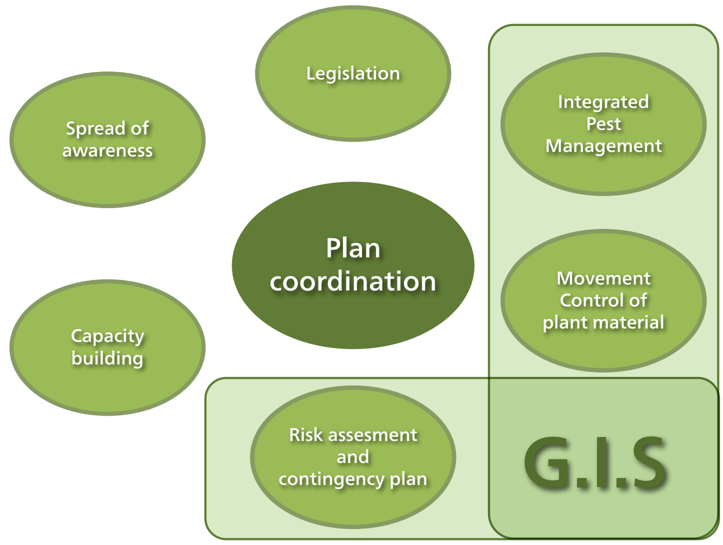
The RPW was first detected in the Canary Islands in September 2005 at the island of Fuerteventura (Martín, 2013). It was found that the introduction came from the importation of date palms from Egypt for ornamental purposes.

The RPW regional eradication program began its work on the field in September 2006. It should be noted that during this year different measures were undertaken: inspections, removal of palm trees and maintenance of traps network. But a sum of measures does not make a program.

2. The Program

The structure of the program is as shown in the following diagram (Figure 6).

Figure 6. Program's structure



2.1. Centralized coordination

Especially in cases that involve different geographical areas, each with their responsible administration, there is a tendency of the projects to be differentiated and localised. Therefore, a centralised coordination, as well as a transparent and consequent organogram, have resulted to be vital to reach the final objectives of the project. The whole team consisted up to 34 persons and at each of the islands was headed by an Island Team Leader.

The more difficult challenges that arose during the development of the project were more linked to management and implementation than to technical-scientific knowledge of the pest. Among others were: Do not lose sight of the objective, building of an efficient team, communication, coordination between institutions and maintenance of protocols.

2.2. Legislatives measures

Since the detection of the RPW in Europe, all administrations have made legislative efforts within the scope of their powers to arm themselves with legal instruments that make it possible to combat RPW. During the development of the eradication program, the basic legislative provisions that establish measures to combat RPW in the Canary Islands were the following:

1. *Commission Decision 2007/365/EC of 25 May 2007* adopting emergency measures to prevent the introduction into and the spread within the European Community of *Rhynchophorus ferrugineus* (Olivier) and its subsequent amendments. (OJ L139 / 24 of 31/05/2007) (OJ L266 / 14 of 07/10/2008) (17/08/2010 DOCE L)
2. *APA / 94/2006 fin, 26 January, amending the Order of 12 March 1987* to prohibit the importation of plants of palm species (Palmae) of more than 5 cm of base diameter in the Autonomous Community of the Canary Islands. BOE No. 24 of 1/28/2006).
3. *Order of 29 October 2007* declaring the existence of pests produced by the harmful agents *Rhynchophorus ferrugineus* (Olivier) and *Diocalandra frumenti* (Fabricius) and establishing the phytosanitary measures for their control and eradication (BOC no. 222, dated 6.11.11/ 2007) Ministry of Agriculture, Livestock, Fisheries and Food.

This chapter is not intended to enter into legislative issues but only to note that the measures included in the regulations at all levels whichcan be divided into two major groups:

1. Those that try to reduce insect dispersion by the people: Import prohibition, quarantine measures and regulations for the movement of plant material, measures obligate for nurseries and farmer, etc.
2. Those that try to reduce the population and dispersion of the insect by itself.

Those of the first group are the most difficult to enforce and are those that can fail a perfectly executed program.

In any case, within the multidisciplinary teams that make up an eradication program the inclusion of legal advice should be valued, to ensure compliance with the measures established in the regulation.

2.3. Spread of awareness

Several information and awareness campaigns were carried out to train and inform all stakeholder and citizens in general in order to obtain the largest number of people involved in the eradication plan.

Those stakeholders were engineers, technicians and workers of the different Public Administrations, gardeners, touristic complexes, gardening companies, nurseries, as well as the whole population in general. The main goal was that in the presence of a palm tree with suspicious symptoms, they can alert the program to be able to act with an immediate response.

The specific methods used are:

- Web page (www.picudorojocanarias.es)
- TV advertising campaigns
- DVD information
- Conferences and special workshops held on all the islands
- Publication of brochures

One of the keys of this group of measures is to openly expose all available information of the program and not hide information. This is the best way for the stakeholder to feel confident and involved in the program.

2.4. Capacity building

The order of October 2007 established the obligation to have an accreditation to work with palm trees. The objective of this accreditation was to ensure that the workers and companies that perform pruning and any labour on palms, knows all the methods and protocols established in the legislation and have the necessary training to ensure proper management.

The contents for the "specialist on labour on palm trees" course were created, organized and delivered several courses for training trainers. These trainers were accredited.

The "Manual of Good Practices in palm trees" was edited by the program to be used as training material.

2.5. Control of plant material's movement

It is well known that the main route of propagation of the pest over long distances is through infested plant material, so it was considered appropriate to establish restrictions and controls on the movements of the palms of plant material.

All nurseries had to be registered and periodic inspections were performed.

To perform transplantation is obligatory authorization of the plant health authorities and have to be carried out by an accredited company. All requests for transplantation of palm trees established in the protection zones of the affected areas (5km) were denied.

2.6. Integrated pest management program

The integrated pest management program was based on the following measures: Visual inspections, removing affected palms, chemical treatments, monitoring/mass trapping and cultural measures. All of them are among the most common measures implemented in all control programs worldwide (Abrahan,1998; Faleiro, 2006).

2.6.1. Zone delimitation

As a palm or group of palms trees affected by RPW were detected as a result of the inspections, an affected area was defined mainly by the following areas:

Intensive surveillance area - Inner circumference area of 1 km radius around the most affected external palm. In this area 100 percent of the palm trees were registered inside lots. Only the palms trees that have been diagnosed as affected were register individually.

Guided surveillance area- Area included within a radius 3 kilometres around the limit of the intensive surveillance area.

2.6.2. Inspections of palm trees.

After testing all possible methods within our reach, we have found that the most effective is the intensive visual inspection. This one consists of a thorough review of the stipe and all the bases of the crown's leaf. This type of inspection was performed by specialized workers.

2.6.2.1. Inspection inside intensive surveillance area

In addition to regular inspections of all palm trees included within the intensive surveillance area, intensive visual inspections were carried out around each trap with capture or new affected palm tree detected. This made it possible to concentrate resources in the most affected areas.

2.6.2.2. "Guided inspections"

The technicians are the ones in charge of the guided surveillance, this consists of visual inspection from the distance of all the palm trees of the "Guided surveillance area" in search of evident symptoms that are easily recognizable. These inspections resulted in the location of affected palm trees outside the intensive surveillance area and beyond.

2.6.2.3. System alert

The program established an alert system in which it was warned by any citizen about palm trees with supposed symptoms of weevil. This has allowed the discovery of 5 new outbreaks in an early stage of development, thus facilitating their control.

The success of this measure is closely linked to outreach the awareness-raising measures (2.3).

2.6.3. Removal of infested palm trees

All palm trees diagnosed as affected by red palm weevil were removed.

The elimination took place, practically on all occasions, in the first 24 hours after the detection and, in case this was not possible, they were treated and enmeshed until the moment of removal.

During removal a strict disposal protocol was followed which aimed to avoid the dispersion of individuals during the process. The stumps were guarded during several days after the removal and a trap was left next to it for at least a week.

2.6.4. Chemical treatments

The chemical treatment aim to control the stages of RPW found in the most superficial part of the palms.

These chemical treatments were sprays at very low pressure and with high volume of dissolution per palm.

Throughout the program chemicals treatments were performed periodically on all the palm trees inside the intensive surveillance area but also around each newly infested palm detected and around traps capturing weevils.

This has allowed the palm trees most likely to be infested to have received chemicals treatments more frequently.

2.6.5. Trap nets

The installation of food baited pheromone traps networks was carried out following different strategies and objectives: mass trapping to attract adult weevil to the center of the affected areas, monitoring populations and detection of new affected areas.

Trap capture data and maintenance were carried out weekly. Traps were placed more than 15 meters from a palm tree, as far as possible half buried in the ground. After Avalos (2010), all traps were painted black for better weevil captures.

Regarding the trap networks management, different management strategies were followed. The program started, as recommended by Oehlschlager (1994), with a grid of 1 trap/ha placed all over the surface of affected areas. This was later replaced by “dynamic micro-networks of traps”, within the polygons formed by the affected palm trees, with a density around 4 traps/ha. They were considered dynamic due to the continuous adjustment and resizing of the micronets.

2.7. Risk assessment and contingency plan

2.7.1. Risk assessment

Risk assessments were carried out on all islands of the archipelago. In islands without outbreaks, traps were placed and surveillance was performed where date palms were imported in the last 5 years (golf course, hotels and newly built housing estates, nurseries, etc.). In this method a new outbreak was detected in the island of Tenerife.

In Islands with affected area, traps were placed around the disposal areas.

2.7.2. Contingency plan

As soon as an affected palm in a new area was detected, a contingency plan was designed and implemented. The purpose of this contingency planwas to establish the measures that allow to determine in a fast and efficient way the outbreak origin and location and disposal of all the infested palm trees.

All the resources of the program were dedicated to the new area until the situation was stabilized

3. Results and Conclusions

After a decade of work, in which was reached up to 16 active affected areas distributed in three islands, where about 40.000 palm trees were registered and 706,081 visuals inspections and 209,547 chemicals treatment were carried out. 681 adults were captured in traps and 660 palm trees removed. In May 2016 the Canary Islands could be declared free of RPW in the last affected area where the pest was detected during 2013.

Figure 7. Number of infested palms

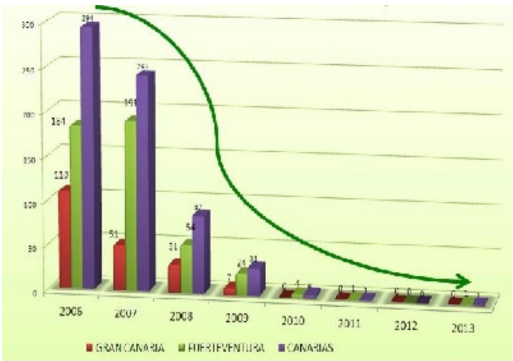
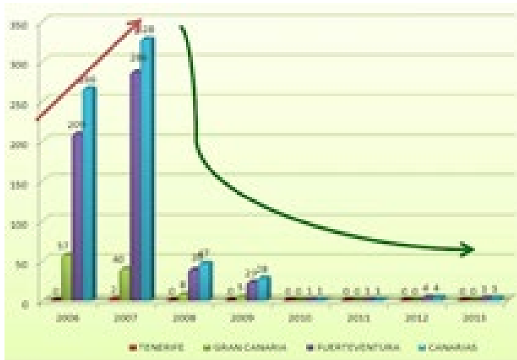


Figure 8. Number of adult weevils captured in traps



These actions, which were carried out by the public company GMR canarias under the Directorate of the Plant Protection Service involved a cost of 9 million euros financed by the Government of the Canary Islands and the Spain Agricultural Ministry.

The Canary Islands example brings some optimism and shows that, under certain conditions, all the knowledge and technique presently available on the RPW can perfectly enable the control/eradication of this pest. The main issue is not the lack of solutions but the efficient implementation and coordination of all measures.

Taking into account the results of the Canary Islands and the experience gained is possible to list the minimum conditions required for successful eradication program:

- Applying a program either in areas of recent introduction or where the RPW was kept under control.
- In isolated areas from other affected areas without program
- Including measures in legislations aim to avoid new introductions and movement of plant material

- Correct design and integrated implementation of all program´s measures
- Provide budget according to needs
- Centralized coordination (communication, decision-making)
- Human resources and its management (training, attitude, motivation, constancy procedures)
- Using a GIS
- Involving all stakeholder,
- Co-operation and coordination with public entities (Provinces, CCAA and affected municipalities) and private (nurseries, gardening companies, farmers)

Now a great new challenge begins in the Canary Islands: to prevent a new introduction of the Red Palm Weevil.

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9. Sustainability, aaplication and delivery mechanism of biological control agents

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Abstract

This contribution focuses on the natural enemies of *Rhynchophorus ferrugineus*, both entomophagous agents and entomopathogenic microorganisms, and on their potential to control this pest. Although there are many references to *R. ferrugineus* natural enemies, very few of them fulfill the requirements for further development to effectively control the red palm weevil (RPW), either by conservation or by augmentative (inoculative and inundative) biological control. Pros and cons of all the biological control agents are discussed, and special attention is given to entomopathogenic fungi (EPF), which are noteworthy the most relevant agents for the natural regulation of *R. ferrugineus* populations and are the most promising for inclusion in RPW IPM programs.

Several strains of EPF have been isolated from diverse naturally infected specimens of RPW in different countries through the Mediterranean Basin and elsewhere. Molecular studies conducted to study the diversity and relationship between some of these strains, with emphasis on *Beauveria* sp., have revealed a host mediated spread of this EPF in the Mediterranean Basin. Most of these fungal strains have environmental competence as revealed by their temperature, humidity and UV-B radiation requirements. Several tactics may be adopted to develop EPF for RPW control, including mycoinsecticide sprays targeting the base of the fronds and EPF-based lure and infect devices, which have shown full potential for effective control in laboratory, semi-field and field trials.

Finally, the potential of insecticidal compounds secreted by EPF for RPW (targeting both adults and larvae) control is highlighted.

10. Recent advances in insecticide treatments against the Red Palm Weevil

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Abstract

In the framework of the fight against a quarantine pest like the red palm weevil (RPW), the interest of insecticide treatments goes far beyond protecting or curing the palms in the infested zones. In the case of treatments by injection, these treatments do not kill the adults but prevent RPW reproduction and multiplication. Regarding the curative treatments, we must speak of sanitation treatments as the main objective of these treatments is not to save the infested palms but to eradicate the weevils that they contain.

The main problem regarding the treatments against the RPW is not really the type of insecticides or of biological agents applied but the way to reach the pest and to increase their persistency.

Regarding preventive treatments, the recent rectification of false ideas on RPW oviposition and the difference that has been established between palms (species and morphology) have led to recommend soaking treatments precisely targeted and differentiated according to the palms.

No significant advance regarding the type of insecticide (synthetic or natural) to be used can be noticed. Many insecticides are efficient against the RPW but treatments must be repeated very frequently to be efficient. Research to increase their persistency has been initiated.

Injection technique for preventive or sanitation treatments can be useful in precise circumstances. The limitation factor is that these treatments cannot be repeated too often as they create a wound that can compartmentalize but will never be covered by new tissues, at the difference of what occurs with trees. For ornamental palms, including ornamental date palms, new injection technique based on micro-infusion of an avermectin insecticide allows to protect the palms very easily and at very low cost over a period of one year.

More generally, it has been confirmed that the use of preventive treatments for an indefinite time leads to an economic, environmental and health impasse: the presence of insecticide residues in dates has been associated in some places to excessive applications of treatments against the RPW. Preventive and sanitation treatments must be applied only in precise circumstances and in the framework of integrated management progamme aimed to obtain the rapid and continued decline of the pest.

Keywords: *Rhynchophorus ferrugineus*, IPM, date palm, ornamental palms, quarantine pest, soaking treatment, injection, emamectin, wound, *Phoenix dactylifera*, *Phoenix canariensis*, oviposition

Introduction

RPW is a deadly pest of date palms (mainly of less than 20 years), of coconut and of some ornamental palms[2] especially *Phoenix canariensis*. Because of the movement of infested palms, RPW has become during the last 50 years the more serious pest of these palm species in more than 60 countries.

In nearly all these countries, RPW is quarantine pest. The purpose of treatments against a quarantine pest is to eradicate, contain or suppress the pest. In this framework, the main objective of the treatments is to eradicate the weevil must be more than to protect or cure the infested palms. Therefore, we must speak in particular of sanitation treatments instead of curative ones. Their objective is to eradicate the weevils that contain within the infested palms and only, if possible, to save the palms. Similarly, the objective of preventive treatments is to kill the adults or to prevent their reproduction and multiplication. This last objective represents the principal interest of the treatments by injection of non-infested palms.

The issue regarding the insecticide treatments is much more how to reach the pest in its different forms rather than the kind of insecticides to apply.

To reach the pest, it is essential to know where it is located. Unfortunately, false ideas regarding insect behavior and oviposition are very common. They have lead to the adoption of inappropriate methods of treatment.

In this paper, we rectify these false ideas and present the corresponding advances that have allowed improving the treatments efficiency. We present also the knowledge acquired regarding the treatments by injection. Finally, we underline

[2] Date palms are mainly grown for date production but they are also frequently planted as ornamental trees in many countries, especially in the NENA region. Ornamental date palms as some other ornamental palms species must be imperatively included in RPW management programmes.

the necessity to conceive and apply strictly these treatments in the framework of an Integrated Pest Management (IPM) programme.

1. Treatments against the adults

1.1 Female oviposition behavior: RPW is not a wound parasite

No previous wounds are necessary for oviposition, contrary to what was written in the first papers published on the RPW in date palm. Furthermore, even if palms are not pruned, RPW will infest them. The only difference between pruned and not pruned palms is that RPW will be preferentially attracted by pruned ones during a short period (Ferry and Gomez, 2012a). The initial mistake regarding the role of wounds has been repeated since that time and unfortunately it is still frequent to find it today. RPW is not a "wound parasite".

For oviposition, females dig holes where they will lay their eggs (Wattanapongsiri, 1966; Abbas 2010; Ince *et al*., 2011). They realize actually an extraordinary ballet: with their mouth at the end of the rostrum, they first dig a hole as deep as possible, by movements up and down and using their legs as a lever its legs as a lever; then, rotates perfectly 180 degrees, extend its ovipositor and insert it as deep as possible in the hole (Ferry and Gomez, 2015). The depth of oviposition holes is strictly limited to the length of the rostrum. But the eggs must be imperatively placed in living tissues for their survival as well as for the survival of the first instars stages. Consequently sites of oviposition are very specific.

1.2 Target sites of oviposition and treatments

Because of the peculiar oviposition behavior of the RPW, many places on the palms cannot constitute oviposition sites although they are often presented as such:

- in date palm, the junction between the offshoot and the mother palm cannot constitute an oviposition site because this junction is far to be accessible to the female mouth.
- the base of the stipe (trunk of the palms) when it is wetted due to flood irrigation can constitute a good harborage for the adults but does not constitute a suitable site of oviposition (dead tissues).
- the cut rachis end of the pruned fronds does not constitute an oviposition site, except if the petiole has been cut enough down to offer a sufficient surface for the oviposition ballet. Nevertheless, during few days, before drying of the wounds, the pruned fronds will attract the females that can hide and lay their eggs at the base of these fronds.

- - stipe covered by old petioles bases don't constitute oviposition sites, except at the level of fresh wounds or if aerial roots development occurs. Such development occurs frequently in date palms but also in some ornamental palms (like Washingtonia sp.). Females can hide between these roots and even if these roots seem dry but are not too old, they are constituted of living tissues that female RPW can reach easily by drilling the oviposition hole.

At the constraint that represents the accessibility of living tissues for oviposition, must be added a specific behavior of the adults: except when they are moving to colonize new palms, they live concealed deeply behind the petioles bases where they can find more suitable environment conditions (shadow, more humidity and mild temperature). It is only exceptionally that oviposition will take place in open space. It can occur for example at the level of fresh wounds resulting from offshoots removal. After few days, wounds lose the attractiveness for oviposition (no more volatiles emission, tissue drying process).

Taking into consideration all these factors, the sites for oviposition are not only specific but will differ between palms species and morphology (Ferry and Gomez, 2011; Ferry and Gomez, 2012a):

- in palms without offshoots (including date palms whose offshoots have been removed) and of more than 2-3 meters' stipe height, the only possible oviposition sites are located at the canopy, more precisely at the bases of the fronds, especially the central ones. The females reach the oviposition sites by flying. RPW is very attracted by the canopy of tall *Phoenix canariensis* where infestation usually occurs in the crown, while infestation in the crown is rather rare in date palm.
- in palms with offshoots or in palms of less than 2-3 m stipe height, the offshoots and the petioles bases on the stipe constitute the oviposition sites. The females reach the oviposition sites mainly by walking and climbing along the stipe. For date palms, it is often stated that the great majority of infested palms have less than 15-20 years. It is because palms of that age present offshoots or are not yet very tall. In fact, it would be much better to use these two parameters than the age to characterize the susceptibility for infestation. In small *Phoenix canariensis* like in date palms with offshoots or of small size, the infestation develops in the stipe without any visible symptoms in the canopy until larvae destroy most of the vascular system, creating huge holes in the stipe.

Treatment must be applied to target these sites, taking into consideration that they differ between these two groups of palms.

1.3 Mode of treatment

The adults hide deeply at the base of the fronds petioles (offshoots or canopy) or, for the small palms, of the petioles bases remaining on the stipe. To reach these locations, the classical insecticide spray treatments are not efficient (Abraham *et al*., 1998; Vidyasagar *et al*., 2000) although it is still frequent to see such mode of treatments applied. The use of systemic insecticides does not improve the result as, in palms; at least *Phoenix canariensis* and *Phoenix dactylifera*, the thick cutin prevents to a large extend the penetration of such insecticides, at least in the case of fully developed fronds (Ferry and Gomez, 2012a).

To be efficient, treatments against adult red palm weevil, for the palms of less than 2-3 meters' stipe height, must consist in soaking the frond bases, the offshoots and the petioles bases remaining on the stipe. For tall palms, mainly *Phoenix canariensis*, the base of the central leaves and medium crown leaves must be soaked (Ferry and Gomez, 2008).

It is better to take off the nozzles of the sprayers to deliver the insecticide solution exactly to these targets. In addition to its efficiency, the advantage of such mode of treatment is to limit the useless dispersion of insecticide and, above all, to increase the persistency of the insecticide: the target zones constitute like a reservoir; part of the insecticide will be absorbed by the fibrillum (frond sheath); the degradation of the insecticide by photolysis will be slower.

2. Treatments against the larvae

The treatments against the larvae have two purposes: to prevent RPW reproduction by killing the larvae at the beginning of the infestation or to sanitize infested palms. These treatments are based on the introduction of the insecticides in the palm tissues where they will be protected from photolysis and consequently will remain efficient during much more time compared with spray or soaking treatments.

2.1 Treatments with systemic insecticides diluted in the irrigation water or injected in the soil

This kind of treatment has been used with good results (Kaakeh, 2006; Dembilio *et al*., 2010). Complementary experiments are necessary to establish the duration of the protective effect and to elaborate detailed protocols taking into consideration the irrigation systems and the insecticides. This kind of treatment presents the inconvenience to pollute the water if groundwater table is closed to the surface. It is forbidden in Europe, excepted for the palms in pots irrigated by drips.

2.2 Treatments by injection

This technique is used for a long time against various pests of palms and especially against the red palm weevil in date palm (Ferry and Gomez, 2014a).

The treatments by injection can have to distinct purposes:

- in non-infested palms to prevent the multiplication of the weevils: the female will succeed to lay their eggs into the palms but the larvae will die.
- in infested palms to kill the larvae, but as the insecticide will not reach the cocoons and adults hidden at the petioles bases, the sanitation operation has to be imperatively completed by soaking the trunk.

The introduction of the insecticide can be obtained by two different systems: a true injection technique where a certain pressure is applied and the infusion method where pressure is null or practically null. This last method was the first to be applied against the RPW, either in coconut or in date palm (Nirula, 1956; Abraham *et al*., 1998). It is based on very simple and cheap technology. Later, pressure injection equipments have been proposed and pressure injection methods are presently dominant. This evolution is not linked with bad results when injecting by infusion. It is mainly the result of commercial propaganda to sell these equipments. Some of them are very sophisticated and expensive without clear evidence of the advantages that they present.

In addition to the analysis cost/benefit, the choice between methods of injection will depend of the volume to inject that is in close relation with the chosen insecticide. This volume varies from few hundred ml per hole to less than 15 ml (micro-injection with non diluted insecticide). Treatments by injection fail often because the dilution of the insecticide is not adapted to the method of injection and consequently the translocation is bad or insufficient to reach the larvae at an efficient concentration. In injection techniques, it is very important to take into consideration not only the active ingredient but also the formulation (Ferry and Gomez 2014a). The adjuvant plays an essential role in the translocation.

Regarding the efficiency of injection techniques, it has been empirically well established and many papers have concluded that it can be very high (Abd-El-Hady, 2011; Estévez *et al*., 2011; Aldawood, 2013; Dembilio *et al*., 2015; Ferry and Gomez, 2015) but it is difficult to compare the results as many parameters differ between protocols. Furthermore, it is important to include bio-assays in the protocols (Estevez *et al*., 2011) as often the original injected active ingredient is not found by chemical analysis because it has been metabolized in a molecule that can be also bioactive and very efficient. Unfortunately, for ignoring this point and also neglecting all the parameters to consider for right injection, it has been concluded sometimes that insecticide translocation in palms was not possible.

2.2.1 The issue of the wounds resulting from such treatments

Treatments by injection are based on introducing an insecticide in the palm through holes in the stipe realized by drilling or by percussion. This technique leads to the creation of wounds. Palms are perfectly capable to "heal" (to compartmentalize) wounds, although the myth (Shigo, 1993) or false idea that they don't have this capacity is largely widespread (Howard *et al*., 2001; Moya *et al*., 2005; Hodel 2009; Dembilio *et al*., 2015). Because of the palms capacity to heal, Tomlinson himself in his famous book on "The structural biology of palms" defended the interest of injection (Tomlinson, 1990).

But, palms like all the plants will never regenerate the wounded tissues. Furthermore, at the difference of the trees they will not cover their wound. Consequently the injection hole will remain and never be closed.

The real wounds can be much more important rather than the injection hole size. Various factors contribute to increase the size of the wounds: high pressure, type of insecticide or dilution Ferry and Gomez 2014a; Ferry and Gomez 2015). Furthermore, some techniques are particularly wrong because they contribute to maintain the wounds opened, instead of enhancing their quick "healing".

Injections are not banal treatments. They can't be repeated indefinitely (Ferry et Gomez 2014a). They must be considered as exceptional treatments when no other efficient treatment is available or affordable.

In the case of pressure injections, it is recommended not to exceed the limit that has been adopted for trees, 2-3 kg/cm^2. The size of the hole must be as small as possible. Regarding Phoenix species, it is not necessary to realize deep holes as the density of vascular system is more important at the periphery. Regarding the number of holes, this parameter cannot follow the rules adopted for trees where the number of holes varies over time because trees diameter increases while palms diameter is constant. The number of holes must be as small as possible but must be sufficient to obtain a good dispersion of the insecticide (Gomez *et al*., 2013).

2.2.2 Injection for sanitation treatments

It is mainly for sanitation that injection is applied in date palms and coconuts. This treatment is based on two different conceptions on the way to reach and kill the larvae:

- by direct contact of the insecticide through reaching and filling the galleries made by the larvae. This technique can be efficient but it requires high pressure, obtained with pumps that can exceed 10 kg/cm2. This pressure will make part of living tissues cells explode. The damages will not be visible. Their consequences will be a harvest decrease. They will also create stipe mechanical weakness that could generate a palm failure risk in the future.
- by absorption of the insecticide in the living tissues. These tissues will be eaten by the larvae that will then die if the insecticide concentration is sufficient.

The insecticide injected will not reached the RPW present in the cocoons or hidden in the offshoots or the petioles bases remaining on the stipe. Therefore, an insecticide soaking treatment must be applied to kill these weevils and avoid the escape of adults during the intervention (Ferry and Gomez, 2012b). The interest of such treatment just after detection is also to stop immediately and easily the possible dispersal of adults and to dispose of a delay to organize the intervention.

The application of injection technique for infested palms sanitation requires a good technical skill as well as various basic equipments even when using infusion method (to drill the hole, to inject the insecticide). Mechanical sanitation represents a much simpler alternative.

2.2.3 Injection for preventive treatments

The concept of preventive treatments by injection in the framework of quarantine pest management is very peculiar. It has an objective quite different from the one pursued with usual preventive treatments. Injections will not kill the adults. They will protect the palms but above all prevent the RPW reproduction and multiplication that constitute an essential goal in the management of a quarantine pest.

For non-ornamental date palms with offshoots, injection treatments are difficult to apply. Offshoots constitute the main oviposition sites for these palms. The mother palm must be injected as low as possible to allow the insecticide that moves mainly upward, to migrate in the offshoots. Injected the offshoots themselves is not very realistic and much more delicate because of the phytotoxique effect on the terminal bud. If all the offshoots have been removed, the treatment is easier to apply and has not to be realized so low. For this type of palms, the interest of this treatment is limited as it cannot be used many times and long persistency insecticide like emamectin benzoate (Ferry and Gomez, 2015) cannot be used because residues can be found in the dates. Such treatment is justified as a complementary component in the case of progamme conceived to eradicate quickly the RPW in a new infested spot or to reduce rapidly the weevil population in a highly infested spot.

The problem is totally different for ornamental palms, including the very numerous ornamental date palms planted for landscaping in the NENA region. Long persistency insecticides present in that case a very great advantage by reducing the number of injections and interventions. Furthermore, in urban environment, the use of this technique is much more practical and health and environment safe that soaking the palms (Ferry and Gomez, 2014b).

An injection treatment that presents a lot of advantages (Ferry and Gomez, 2015) has been developed few years ago. It is based on the micro-injection by infusion of a micro-emulsion of emamectin benzoate at 5% that protects the palms during one year. The treatment is very simple to apply: it consists to drill small holes (10 mm diameter; 10-15 cm depth in the real stipe), 4 holes for normal diameter *Phoenix canariensis* or 3 holes for normal diameter *Phoenix dactylifera*, and to fill them with a simple and low cost device (dosing gun). The intervention is very rapid (2-3 minutes per palm) and safe. At the price of this insecticide available in various NENA countries, we evaluate the total cost of the treatment at 2-3 Euros per palm, per year.

3. Treatment of quarantine

Al-Shawaf *et al.*, 2013, propose a dipping treatment with fipronil 0.004% for 30 minutes to assure that offshoots are RPW free. As the issue of pest free offshoots movement is absolutely crucial, it is recommended to repeat this trial for confirmation if required, including chemical analysis of the palm tissue to eliminate possible bias.

4. Synthetic insecticides and natural products

Papers regarding the efficiency of synthetic insecticides against the different RPW stages are numerous. It can be concluded that most of the usual insecticides are efficient against the RPW. Nevertheless, in many countries, an important proportion of these insecticides is or will be soon forbidden.

There is one group of insecticides, the neonicotinoids that offers a great advantage and belong to the insecticides that present nowadays the lowest risk for the human health. The risk phrases are few and relatively benign, similar to those of various natural products or biological agents. However, the use of neonicotinoids insecticides is highly problematic in places with crops pollinated by bees and pollinators. But, *Phoenix dactylifera* and *Phoenix canariensis* are not entomophilous species and have no nectarifer organs. The advantage of neonicotinoids insecticides is also that, as one of the target treatment zones is the base of the palms, part of the insecticide will fall down and will be absorbed by the roots.

Regarding natural products, neem extracts are quoted for a long time but their efficiency to control the RPW is controversial. Experimentations are on progress in various laboratories to find new products (plants extracts, essential oils, special diatomaceous earth). Other experimentations are carried on to increase the persistence of synthetic insecticides.

5. The issue of chemical residues

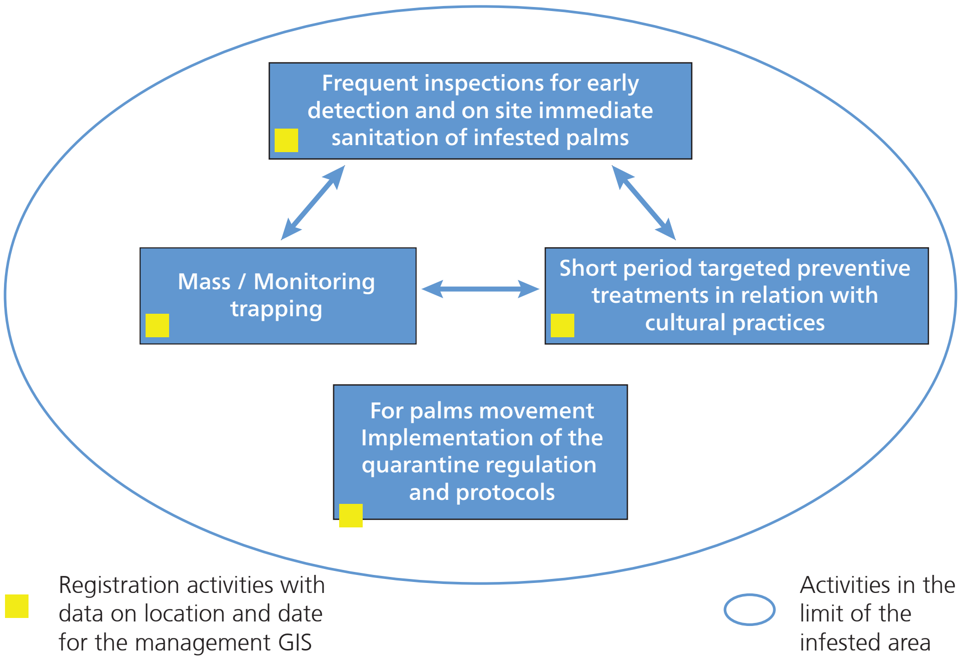
One of the first concerns in the use of insecticide treatments for productive date palms is relative to the issue of insecticide residues in the dates (Khan *et al* 2001; Al-Samarrie and Akela, 2011; Abd Rabou *et al*., 2015). A delay before harvest must respected according to the insecticide applied and the way to apply it (soaking, injection curative or preventive treatments). Chlorpyrifos was found to be the highest residual detected pesticide in Riyadh dates (El–Saeid and Al-Dosari, 2010).

Anyway, frequent insecticide treatments, during an indefinite time, are unsustainable. This creates a health risk for the workers and for oasis inhabitants. They end polluting water and soil.

6. Insecticide treatments as one of the components of the RPW integrated management

It is compulsory in Europe since 01/01/14 to control a pest by applying the principles of Integrated Pest Management. Nevertheless, the effectiveness of the insecticide treatments for RPW management is very often assessed without taking into consideration that these treatments have to be considered imperatively as one of the components of an IPM programme. They have to be applied with other components and in strong inter-action with them.

The following diagram presents this integration and inter-action:



Such IPM approach has been applied in Saudi Arabia from 1993 (Abraham *et al.*, 1998) and is now applied in most of the infested countries (Al-Dosary *et al.*, 2016). It is also similar to the approach proposed for the management of the RPW in urban environment (Gomez and Ferry, 2007; Gomez *et al.*, 2009; Paz *et al.*, 2010).

Unfortunately, the implementation of each of its different components has not been realized enough efficiently to avoid the extensive spreading of the pest. A lot of efforts and means have been dedicated to infested palms eradication, leaving not enough means for the right implementation of the others components and for the involvement of the farmers, ornamental palms owners and other stakeholders in the management of the pest. Regarding the intervention on infested palms (at the stipe level or in the canopy), the adoption of low cost alternative solutions with in situ sanitation (Ferry and Gomez, 2008) has been recommended, based on better knowledge of the pest. It has been established that larvae are not xylophagous (Ferry and Gomez, 2011). They don't ingest the palm fibre; they just chew it and suck the extracted liquid. Consequently, they will not survive in palm drying tissue. Therefore, it is useless to shred or to burn non infested parts (especially non infested parts of the stipe). For the infested parts, it is sufficient to cut them in small pieces and to let them dry.

In this framework of the IPM program, the different preventive treatments by soaking that have to be applied in complementary way with the other components or in relation with cultivation practices correspond to the following cases:

- on the palms located close to a trap to kill the adults that will be attracted by the traps but will prefer the surrounding palms.
- on the palms around a newly detected infested palm, or around a trap that captures an increasing number of weevils, or in the whole infested area for few months to contribute to the quick eradication in this area.
- when pruning the offshoots or palms fronds. Severe pruning of the offshoots is necessary to inspect efficiently the palms.
- when removing the offshoots for better inspection, sanitation or transplantation.
- before mechanical sanitation on the infested palm itself to kill the adults hidden in the offshoots, in the cocoons, behind the petioles bases remaining on the stipe, behind the fronds bases of the canopy, and after this operation to kill the adults that will be attracted by the wastes or by the wounded palm itself if it has been maintained.
- before chemical sanitation by injection to kill the adults hidden in the same places as mentioned above.

The objective of these treatments is not repulsive but to kill the weevils. Fresh wounds and fresh wastes must not be considered as a danger but as a way, during the short period of attraction, to attract the females and kill them.

The objective of preventive treatments by injection on ornamental palms including ornamental date palms that have been planted in large number in NENA countries is to protect them but mainly to prevent the reproduction and multiplication of the RPW.

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11. Towards user-friendly early detection acoustic devices and automated monitoring for Red Palm Weevil management

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Abstract

Early detection of hidden Red Palm Weevil (RPW) infestations in field environments is a difficult but important component of RPW management. Unfortunately there are few externally visible signs of early infestation, and scouts trying to survey and target them must carefully inspect the bases or crowns of palm trees to discover adult entry holes in individual trees. Larvae can be detected by acoustic methods, but with current technology, skilled persons must identify where to insert acoustic probes, and they must use complicated signal analyses to help distinguish RPW sounds from other insects and background noise. Each field location has somewhat different background noise, and it is best to measure general background noise spectral profiles, i.e., "background sound fingerprints," in advance to optimize RPW identification. In addition, inspections must be done when it is quietest, usually early in the day, to optimize detectability. With the adoption of such measurement procedures, current technology has been successful in detecting RPW infestations in field tests in the Caribbean, Spain, Saudi Arabia, and Israel. Experience gained from these studies is being applied towards development of user-friendly, low-cost detection devices.

Recent increases in the computing power and a decrease in the costs of microcontroller systems has generated considerable interest in their use for insect pest management. In this report, we present examples of how combinations of microcontrollers with extremely sensitive piezoelectric devices or inexpensive microphone systems can be used for auralization, storage, and digital signal processing of insect sounds in trees in field environments. Progress also is occurring in the development of Matlab and other software to automate and optimize the discrimination of insect sounds from background noise on microcontroller platforms. Further development of these hardware and software tools has potential to expand the applicability of early detection technology so that it is not just useful for research but becomes a widely used tool for RPW pest management.

Keywords: behavior, spectral fingerprint, microcontroller, scouting, mapping.

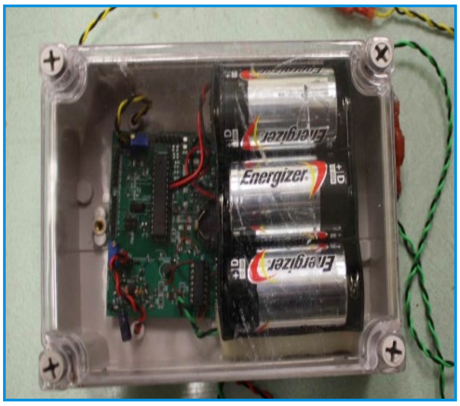
1. Current acoustic detection technology

Because RPW larvae feed internally in palm tree trunks, they are difficult to detect in palm groves before the occurrence of economic damage, and infested offshoots or trees often are transported inadvertently to nearby orchards; consequently, early detection has become an important component of RPW management (Mukhtar *et al*., 2011). Acoustic technology has been used for detection of hidden RPW infestations since von Laar, 2002 and Al Manie *et al*., 2003, began investigations early in this century. All stages of large *Rhynchophorus* spp. can be detected acoustically except for the egg (Herrick and Mankin, 2012; Dosunmu *et al*., 2014).

Several different types of acoustic detection system have been used successfully to detect RPW larval sounds in the laboratory and the field, e.g. (Pinhas *et al*., 2008, Potamitis *et al*., 2009, Siriwardena *et al*., 2010, Rach *et al*., 2013, Mankin *et al*., 2016a), and automated systems have been developed that identify spectral and temporal patterns in the RPW larval feeding and movement activities which help distinguish the larval sounds from background noise (Pinhas *et al*. 2008, Mankin *et al*. 2008a,b). It is frequently observed, however, that scouts and grove managers would benefit from lower-cost, more user-friendly and more automated systems. In addition, some of the components of the originally developed systems are no longer sold, including the digital recorders previously used in field studies (Model HD-P2, TEAC Corp. Montebello, CA; and model PMD661, Marantz, Mahwah, NJ). Thus it is necessary to update recommendations continually for equipment most useful for RPW acoustic detection. To address such concerns, electronic microcontroller systems and embedded software have been developed that reduce costs and improve the user-friendliness of the acoustic detection systems.

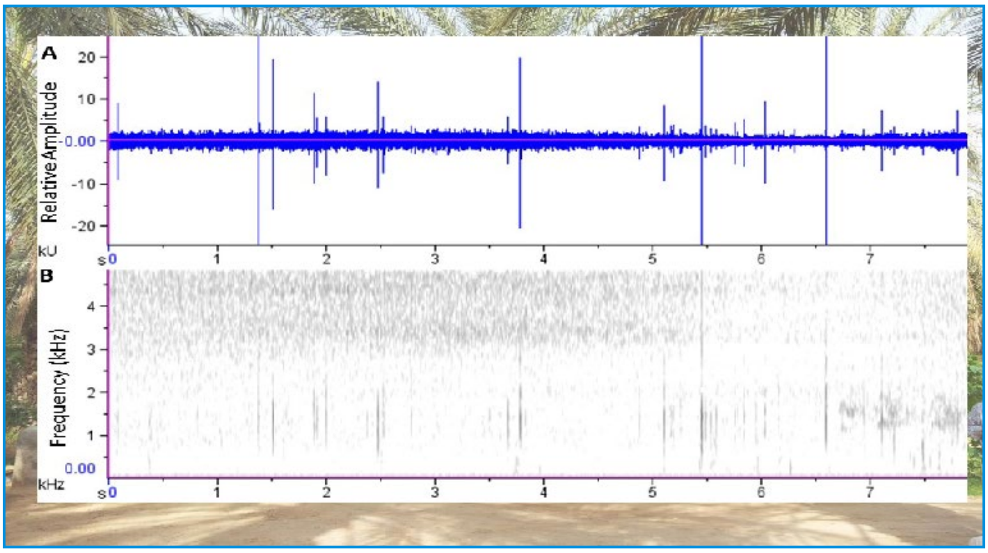
2. Novel automated microcontroller platforms for RPW acoustic detection

Figure 9. Prototype insect acoustic detector in a waterproofed box with external connections from two contact microphones



The introduction of microcontroller platforms such as Arduino Uno (Arduino Inc., Ivrea Italy) and Atmel SAMG55 (Atmel, San Jose, CA) has enabled development of low-cost detection systems that retain many features of the existing instruments while providing on-board signal processing and memory storage (Mankin *et al.*, 2016b), a prototype of which is shown above in Fig. 1. In field studies with red maple trees infested with Asian longhorned beetle larvae that are similar in size to RPW (Mankin *et al.*, 2008b), the effectiveness of low-cost electret microphones was compared to piezoelectric sensors that had greater overall sensitivity but much higher cost. The primary microphone was attached to the trunk near the expected location of a larva. To reduce the effects of background noise, two microphones were included in the system and signals from the second microphone, connected to the trunk about 0.5 m from the recording site, were subtracted from the primary microphone. This canceled out many background signals initiated at long distances from the recording site. Examples of sounds collected by the prototype are shown in Fig. 2.

Figure 10. Examples of vibrational signals recorded from Asian longhorned beetle larvae (horizontal axis is scaled in seconds): A) oscillogram showing multiple impulses, B) spectrogram showing signal energy at different frequencies, with darker shades of impulses indicating frequencies of greatest energy.



The prototype system recorded and analyzed larval sounds with frequencies up to about 5 kHz with good fidelity for 10% of the cost of an AED-2010 system with digital recorder. However, the microphone was damaged easily when moving among different recording sites, and other options to improve the robustness and ease of use of the prototype are being tested. Some of the software needed for improved automated discrimination of insect sounds from background noise can be implemented only on larger microcontroller platforms that are more costly than the current version. Consequently, it is anticipated that newer versions will include faster digital processing and more memory, and power will be consumed at a lower rate to extend battery life. Because many of the current field studies make use of Global Positioning System (GPS) coordinates for mapping of RPW infestations (e.g. Mankin *et al.*, 2016a), the new devices could be made more user-friendly by including GPS features in the software. Additionally, prototypes are under construction that incorporates piezoelectric sensors, which are more sensitive to insect vibrations than the lower-cost electret microphones.

3. Other recently reported automated RPW monitoring devices

In addition to the prototype acoustic detection device, reports of other automated monitoring devices have been advertised recently or reported in journals. An example is a report from www.agrint.net about seismic, smart sensors for in-tree RPW detection. Potamitis and Rigakis (2015) reported on an automated pheromone E-trap for RPW that uses an optoelectronic sensor coupled to a microcontroller platform to sense when the insect falls into the pheromone trap and then transmits time of detection to a cell phone or network interface linked through a Global System for Mobile communications protocols. Psirofonia *et al.* (2017) reported on the use of unmanned aerial vehicles to identify visible signs of RPW infestation in palm tree plantations. Agenor Mafra-Neto of Iscatech (Riverside, CA) produces similar technology. Pontikakos *et al.*, 2015, reported on a location-aware risk assessment system for management of RPW in urban areas. Real-time mapping of field-site status is offered by DroneDeploy.com (San Francisco, CA), which may be useful to identify potentially infested trees in areas without access to cloud services. All of these devices have incorporated GPS features into their software for ease of mapping infestations.

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12. Detection of Red Palm Weevil infestation

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Abstract:

In recent years invasive palm borers and especially *Rhynchophorus ferrugineus*, (Coleoptera, Curculionidae) (RPW) has been spreading nearly without interference over the world causing severe damages to the agriculture sector and urban landscaping. The spread of RPW along the Mediterranean coast suggests that authorities are in shortage of practical tools for timely detection and management efficacy evaluation of this pest. Early detection of borers in general and RPW in particular, is a great challenge as the borer's long development is concealed from inspectors' eyes, inside the tree stem or crown. Early detection of RPW infestation is crucial because at an early infestation stage, palms can be treated more efficiently and saved. Detection is often particularly problematic since not all palms can be accessed and inspected directly and/or due to high cost of actions. Several approaches and techniques were undertaken to enhance efficient detection of infested palms: (1) chemical detection of infested trees by trained dogs or electronic nose; (2) acoustic detection, which identifies gnawing sounds of RPW larvae, produced as they chew and move within the infested palms; (3) detection by thermal imaging based on physiological changes in infested palms that can be sensed through inspection of the thermal spectrum of the irradiation emitted from the tree canopy; (4) monitoring of RPW populations, which is often based on weevil captures in surveillance traps. Advances in each of these detection techniques, their advantages, pitfalls, and potential implementation in area wide detection as well as future directions in development of detection methods are discussed.

Keywords: detection; visual, chemical, sniffer dogs, thermal, pheromone traps, palm trees

Introduction:

Management of any pest requires accurate monitoring of pest population, forecasting its dispersal and evaluating the success of eradication efforts. Red palm weevil (RPW, *Rhynchophorus ferrugineus* Olivier, 1790) though originated in tropical areas has settled in the recent years in temperate areas with a Mediterranean basin and into arid climate of desert oases, and has adapted to palms species that are not present in its native habitat (Rochat *et al*., 2017). Global RPW invasion is largely human mediated, but on the local scale its spread is likely to be a result of its good flying skills (Peri *et al*., 2017).

Palms have only a single meristem situated within the palm heart at the center of the crown, at the top of each stem, generating all organs. If palm heart is seriously damaged, the palm dies. As a monocot tree, it cannot cure internal stem cavities caused by pests (Cohen, 2017), therefore, detection of RPW infestation is particularly crucial at early infestation stage, before apical meristem is damaged and while the trunk is still stable. At this stage, the recovering of the palm is still possible with available protocols and tools (e.g. mechanical sanitation, chemical and/or biological treatments, etc.).

RPW is an invasive quarantine pest and as such needs to be controlled at international check points. As RPW is developing inside the palm, well hidden from human eye, detection of infested palms is challenging. Various methods and approaches were evaluated over the years for early detection of RPW infestations. A worthy detection method has to be fast, accurate, non-destructive, and at affordable cost. Below is a short review of recently developed detection methods and approaches. Their advantages, pitfalls, and potential implementation in RPW management are discussed. In particularly in this summary we focus on visual, thermal and chemical detection as well as on monitoring with traps. Acoustic detection, which identifies gnawing sounds of RPW larvae, produced as they chew and move within the infested palms has been also intensively evaluated over the years. For details about advances in acoustic monitoring, please see Mankin (2017 this volume and also Soroker *et al*., 2017a and Hetzroni *et al*., 2016).

1. Visual inspection

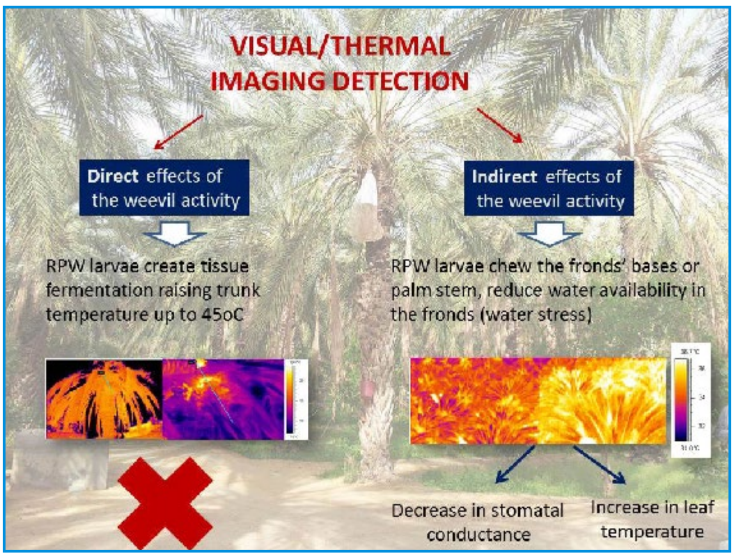
The most obvious approach to infestation detection is visual examination of the palm tree: its crown, along the stem, the offshoots (if present) and around the palm base. These can be: holes on the trunk and at the bases of frond's petiole; oozing, frass composed of chewed plant tissue with fermenting odor; remains of weevils and their pupae cocoons around the tree; and at the most severe cases of infestation breaking of trunk or the crown (Kontodimas *et al*., 2016). The symptoms dependent on the palm species, site of infestation, physiological age and the status of the attacked palm. For example, in date palms (*Phoenix dactylifera* L.), the lower part of the stem and young offshoots are the major sites of attack. Usually, symptoms remain hidden and the palm may appear healthy until it collapses. In some cases, especially in young palms with offshoots, dry offshoots or oozing wounds may be observed. Oozing from the stem was also observed in another palm species such as *Ravenea* and *Syagrus*. Crown infestation is common with Canary island date palms (*Phoenix canariensis* Hort. ex Chabaud), where changes in leaflets and crown symmetry appears. Similarly, coconut (*Cocos nucifera* L.) inner crown fronds tend to wilt. Visual symptoms associated with RPW infestation were recently reviewed by Kontodimas and coworkers (2017). Most of the described symptoms are not specific to RPW infestation and can also be caused by other palm pests or physiological factors. Thus, in the places where RPW presence is suspected, symptomatic palms deserve detailed inspection to verify presence of any developmental stages of this pest.

2. Thermal detection

Individual visual inspection of thousands of palms in commercial plantations or public areas is highly laborious or even unfeasible. Moreover, palms are not always accessible, making their direct inspection impossible. All these make conventional visual detection of RPW infestation not only laborious and costly but also inaccurate; especially in cases were the damage occurs below the crown. This situation calls for large scale-area wide detection methods. One alternative approach is using thermal imaging to monitor physiological changes occurring in the tree due to RPW infestations. Two types of approaches were evaluated: 1. monitoring local increase in stem temperature (4 to 26°C above the ambient level) caused by intensive fermentation of plant tissues following feeding activity of the weevil larvae, (Abe *et al*., 2010; El-Faki *et al*., 2016; Soroker *et al*., 2017a); 2. monitoring water stress of the palm due to damages to the palm's vascular system caused by larvae tunneling the stem tissue, as was recently used by Cohen *et al*., 2012 to map water status of date palm trees on a commercial scale (fig 1).

Although the temperature increases at the center of the crown by the fermenting tissues is drastic, in heavily infested canary palms, it is rather difficult to monitor as the stem surface remains at the ambient temperature due to the natural insulation provided by the palms tissue. Temperature increase can be only monitored via probes inserted into the palm stem as in El-Faki *et al*., 2016. On the other hand, the change in "crop-water-status" that reflects the decrease in stomatal conductance cause an increase in canopy temperature that can be detected. The latter changes were successfully detected in the RPW infested date palms through inspection of the thermal portion of the spectrum of the reflected irradiation, before any visible symptoms were detected (Golomb *et al*., 2015). Remote thermal canopy imaging can be acquired by aerial photography (drones or airplanes). These recent technological advances offer the potential to acquire spatial information and thus facilitate the mapping of palm canopy temperatures of wide region at one aerial imaging campaign. A map of the plants' water-status distribution can, thus, be produced to identify palm trees suspected of being infested providing an alternative to point measurements. Unfortunately, this technology is still not matured enough to become operational for RPW detection, partially because water status of trees can be highly variable in wide area due to differences in biotic and abiotic factors. Future work should be concentrated on automation and development of adaptive algorithms.

Figure 11. Thermal imaging of red palm infestation. Red palm weevil infestation can cause increase in palm temperature in two ways: direct increase in internal stem temperature due to intensive tissue fermentation or indirectly increasing frond temperature due to water stress of the palm following weevil damage to the stem vascular system. Stem temperature increase is scarcely detectable from the outside while even small changes in crown temperature can be detected from above by dedicated equipment.



3. Chemical detection

The potential of chemical detection is based on the assumption that RPW infested palms emit characteristic volatile cues. These may be derived directly from the insect or their frass, the wounds in the infested palm, or they may be herbivore-induced. Thick brown and repulsively-smelling oozing liquids are often associated with RPW infested palms. Some volatiles from RPW infested *P. canariensis* have been reported (Vacas *et al*., 2014). In preliminary studies under semi-natural condition Goldenberg (unpublished) found that the amount of volatiles produced by *P. dactylifera* is very low but some changes in volatile emission can be observed, as the infestation progress. Thus, it is likely that chemical detection can be performed using targeted olfactory sensors (electronic nose or tongue). A study conducted in Italy provided promising results in *P. canariensis* (Littardi *et al*., 2013; Rizzolo *et al*., 2013). However, the chemical detection approach for RPW-infested palms has been successfully tested so far only by sniffing dogs.

Domestic dogs (*Canis familiaris*) are well known for their superior chemo-detection abilities, and have been previously reported to detect infested plant material (Wallner and Ellis 1976; Welch, 1990; Schlyter, 2012). A variety of dog breeds have been employed in the past for diverse sniffing tasks. In relation to RPW detection, breeds such as Labrador and German shepherd have been intensively studied (Nakash *et al*., 2000; Suma *et al*., 2014). After a 6-month training period, dogs were more than 70% accurate in finding the artificially infested canary palms with either larval instars or adult weevils of both sexes (Suma *et al*., 2014). Although palm species are likely to vary in their volatile profiles, thereby affecting detection sensitivity, once trained the dogs were able to successfully detect RPW-infestation in several palm species, in semi-field condition. The accuracy of detection in the most sensitive host, the Canary palm, was above 80% even when palms were infested with one (<1 cm in length) larvae (Soroker *et al*., 2017a). It is worth to indicate that at least in one case a trained dog was able to detect crown infestation in the Canary palm before any visual symptoms were visible. However, sensitivity of detection in different species and conditions requires further studies.

As any living organisms, sniffing dogs working abilities are constrained, they get tired, and their working rates decline with higher ambient temperatures. Abiotic factors such as wind also have negative effects on dog sensitivity. Still, sniffing dogs have several advantages as detectors as being indifferent to pest activity. Once well-trained, the dogs, remember the smell they were trained for throughout their lives. They can be trained to detect many different smells, and therefore the same dog can be used for several sniffing purposes. Still few pitfalls require consideration: a dog implementation requires professional and trained personal. It is not yet clear if dogs are able to discriminate between actively infested palms and treated palms with past infestation. The effectiveness of sniffing dogs in detecting infestation in crowns of tall trees is also still questionable.

4. Detection of RPW by monitoring traps

Monitoring traps are a common tool in pest management. This tool is especially significant for pests spending most of their life cycle concealed within the palm tissues. The surveillance traps serve as "eyes" to evaluate pest population dynamics and abundance in time and space. Male RPW produce pheromones that attract both males and females. Synthetic RPW aggregation pheromone (mix of two components: 4-methyl-5-nonanol (ferrugineol) and 4-methyl-5-nonanone (ferruginone)) is available from different companies. Commercial lures of the pheromone and the trap shape affect their function and need to be tested for the local conditions. Comparative studies have shown that pheromone emission can vary over a wide range (4-50 mg/day) without affecting RPW-trapping efficacy. In addition to the pheromone, composition of the host-plant volatiles plays an important role. The fresh bait material is often expensive, inaccessible, variable and unstable; the best solution is to replace the natural kairomones (host attractants) with a synthetic mixture. Mixture of ethyl acetate and ethanol (1:3) was recently shown as a good replacement of sugar molasses (Vacas *et al.*, 2013; 2014; 2017; Soroker *et al.*, 2017b).

Trap efficacy (the proportion of weevils captured relative to the total number of weevils attracted to the trap's vicinity) is, generally, dependent not only on the lure but also on trap design and position. Over the years' different trap designs as well as colors have been evaluated starting from commercial log made to various plastic designs. Until recently, bucket-type traps were the most widespread model used to trap RPWs, fitting of a funnel inside the standard bucket further improves catches by the insecticide free traps. As the weevils find its way inside the trap by crawling, traps entry needs to be facilitated by creating gentle slopes and ruff surfaces on the trap exterior. Another factor studied aiming to improve trapping efficacy is trap color. Black or reddish-brown buckets were found to achieve significantly more RPW captures than white ones. Taking into consideration previously discussed requirements of shape, color and texture, commercial Picusan® trap, incorporate all the above features and appear superior to most traditional black or white bucket traps.

Trap spatial distribution is another important issue to be considered. Traps require regular maintenance, otherwise not only they may lose their efficiency but when not properly maintained they may even jeopardize the neighbour palms, if weevils will be attracted but not trapped. Being a rather expensive operation in terms of the involved labor cost, decisions on trap distribution are mostly economics based and less on the pest's spatio-temporal behavior. The effective range covered by each trap is difficult to determine. Geostatistical tools have been implemented to tackle the challenge. Geostatistical analysis of spatial autocorrelation of trapping suggested a density of 1 trap per 0.35 ha (60X60m) for monitoring in date plantations and 1 trap per 0.5 ha in urban areas or spaced no less than 75 m apart (Soroker *et al.*, 2017a).

Summary and conclusions

Current state of knowledge indicates that, although no single method perfectly detects RPW infestation, a combination of detection tools can provide almost 100 percent successes, in particular, for trade and quarantine facilities. Weevil infestation can be detected before any symptoms become visible, by sniffing dogs and acoustic. We believe that given that both male and female weevils are attracted to the pheromone baited trap, the latter is a basic tool to monitor the presence of this pest at any location and especially as a tool for early detection of invasion in the area. It is especially useful for large and partly inaccessible areas. Thermal imaging detection of palm damage symptoms is feasible, yet the methodology is still at initial stages of development. Regular visual monitoring is important but highly inaccurate especially in date palms. Considerations for selection of detection tool for quarantine facilities and open areas are summarized in table 1.

Regardless of the selected detection means, acquired data on RPW dispersal and infestations in these areas requires geographic positioning. Systematic Geographic Information System (GIS) linked data collection is indispensable, e.g. using a large number of mapped (traps and weevil catches) the temporal as well as geographical changes in pest distribution can be monitored and infested palms detected by various means can be localized. Such a system might be based on Internet applications, and a graphical user interface (GUI) to produce and display spatial and temporal information to support application decisions. Moreover, high accessibility to mobile GIS devices enables the development of location-aware monitoring and facilitates the collection of real-time agro-environmental data (Papadopoulos *et al.*, 2003; Hetzroni *et al.*, 2009). Systematic accumulation of information concerning pest distribution and host (palm) distribution and condition, along with treatment history, is the basis for the decision-making processes.

Table 1: Considerations for selection of detection techniques for small area e.g. quarantine facilities (local) and large open areas (area wide). Damaged palm- palms that were damaged by RPW but do not longer contain any stages of the weevil, this unlike palms with "active infestation" containing weevils or their developmental stages. + Suitable; - unsuitable; +/- imprecise; *- not yet operational, **- depends on site and degree of infestation

Means	Area wide			Local	
	Palms with active infestation	RPW damaged palm	Early detection of RPW invasion	Palms with active infestation	RPW damaged palm
Traps	+/-	-	+	+/-	-
Visual inspection	-	+/-**	-	-	+/-**
Thermal	+/-*	+*	-	+/-	+
Dogs	+/-	+	-	+/-	+
Acoustic	+*	-	-	**+**	**-**

In conclusion, we would like to emphasize the main future challenges: Automatic detection by affordable electronic equipment; remote sensing from aerial and satellite photography for area wide detection; integration of information from different sensors and risk assessment at real time.

Acknowledgments

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13. Innovative solutions using modern technologies for better management, control and analysis of *Rhynchophorus ferrugineus* eradication

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Abstract

Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* (Olivier), is a key pest associated with various palm species, including ornamental palms and coconuts. It was reported in the early 1980s and is now found in various regions and countries that span Asia, Africa, the Near East, Europe, Oceania, the Caribbean and the United States, causing an annual estimated loss of USD 6–26 million that is increasing on average about five percent per year.

A variety of strategies, methodologies, research and solutions have been proposed and developed during the past few decades to fight and eradicate RPW in infested areas but these have not been fully implemented. There is an urgent need to address RPW in a coherent manner at the local, national, regional and global levels in order to effectively and efficiently manage the pest on a sustainable basis.

In addition to a more global approach, the application of innovative solutions, including the integration of modern technologies such as Google Earth Engine, UAVs (drones), mobile devices, GIS, Internet of things (IoTs) such as smart traps and sensors, within the local context and conditions would further assist in:

- effective data collection and data management;
- effective planning and management;
- spatial management and visualization of the managed sites;
- spatial analysis for optimal decision-making;
- efficient management and optimization of human and technological resources;
- automated identification of the palm crops (where high resolution is available);
- program assessment and review of efficiency and effectiveness;
- assessment of the results and achievement of the objectives from readily available quality information;
- assessment of traps, servicing and workers;

- improvement of the communication at national, regional and global levels;
- migration and movement of palms including quarantine;
- implementation of the innovative solutions for improved monitoring as applicable.

Keywords: GIS, *Rhynchophorus ferrugineus*, Red Palm Weevil, palm trees, decision-making, eradication program, Earth Engine, UAVs, drones, IoTs, innovation

14. Use of GIS (Geographical Information System) for data management and analysis in a Rhynchophorus ferrugineus eradication program

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Abstract

After the first detection of *Rhynchophorus ferrugineus* in the Canary Islands in 2005, the General Directorate of Agriculture implemented the Red Palm Weevil (RPW) regional eradication program. In order to manage the data (collection, transmission, management, analysis and outputs) a GIS was developed. This GIS included: Database, mobile application, web application, and web viewer.

Data Collection of the designed parameters (infested palm trees, traps, locations…) was done across a specific application installed in PDAs. Further, the reporting was done through GPRS systems to a geodatabase, located at a SQL Server Data Base, which had a high capacity of storage.

In order to improve access to spatial information, a web viewer was developed with the help of various GIS tools (ArGIS 9.2, ArcSDE on SQL Server and ArcGIS Server), on which, in addition to the Georeferenced data (Locations, lots, palm trees, traps), it was also possible to represent other queries that were necessary for decision-making.

In May 2016 the Canary Islands were declared a RPW free area. The GIS is considered an essential tool for the planning and effective coordination of the eradication pest program.

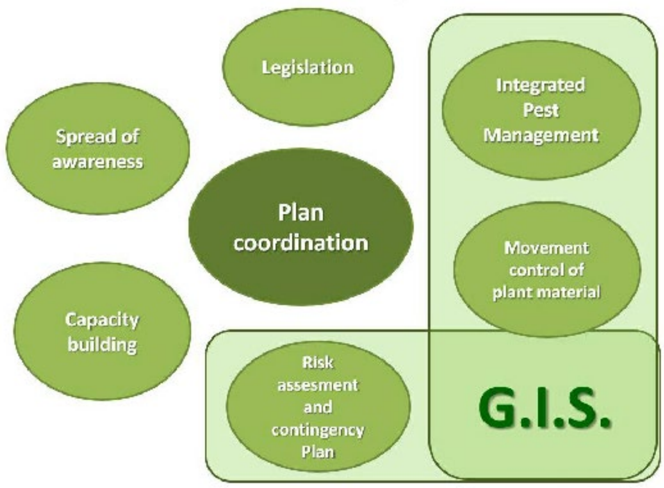
Keywords: GIS, *Rhynchophorus ferrugineus*, Red Palm Weevil, palm trees, decision-making, eradication program

1. Introduction

After the first detection of *Rhynchophorus ferrugineus* in the Canary Islands in 2005, the regional Government entrusted to the public company GMR Canarias the implementation of the Red Palm Weevil (RPW) eradication program.

A program was designed that had the following major group:

Figure 12. Program's structure



This program (Fig.1) was given a budget that included a programming team (ITs) which would be responsible of developing the Geographical Information Systems applications (GIS).

The GIS was the main tool of support for the decision making in three of the major groups: integrated pest management program, movement control of plant material and contingency plans.

The integrated pest management program was based on the following measures: visual inspections, removing affected palms, chemical treatments, monitoring/ mass trapping and cultural measures. All of them are the most common measures implemented in all control programs worldwide.

In the initial phase the program was implemented in 16 active affected areas distributed in three islands, where about 40,000 palm trees were registered. During a decade 706,081 visuals inspections and 209,547 chemicals treatment were carried out. 681 adults were captured in traps and 660 palm trees were removed. The wide geographical dispersion and large amount of data are the keys to the importance of using a GIS.

Geographical information system

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data. The GIS developed consisted of 4 important parts: mobile app, database, web application and web viewer.

2.1 Database

The main objective of the Database is to store centralised all the information concerning:

- Elements: Affected areas, block of palm trees, palm trees, traps, nurseries, etc.
- Activities: removed affected palm trees, inspections, chemical treatments, etc.
- Results: weevil catch, inspection results, etc.
- Resources: workers, types of chemical products, types of traps, pheromones, etc.

In short, it stores all the information that was used during the development of the project. All other applications developed were to interact with the database, either to introduce new values (field-collected with the mobile device) or for the processing of information (generation of reports, elaboration of customized maps, etc.)

All this information was conveniently organized and related. Selecting the correct design of the database at the beginning of the program is very important. The chosen database server was Microsoft SQL-Server.

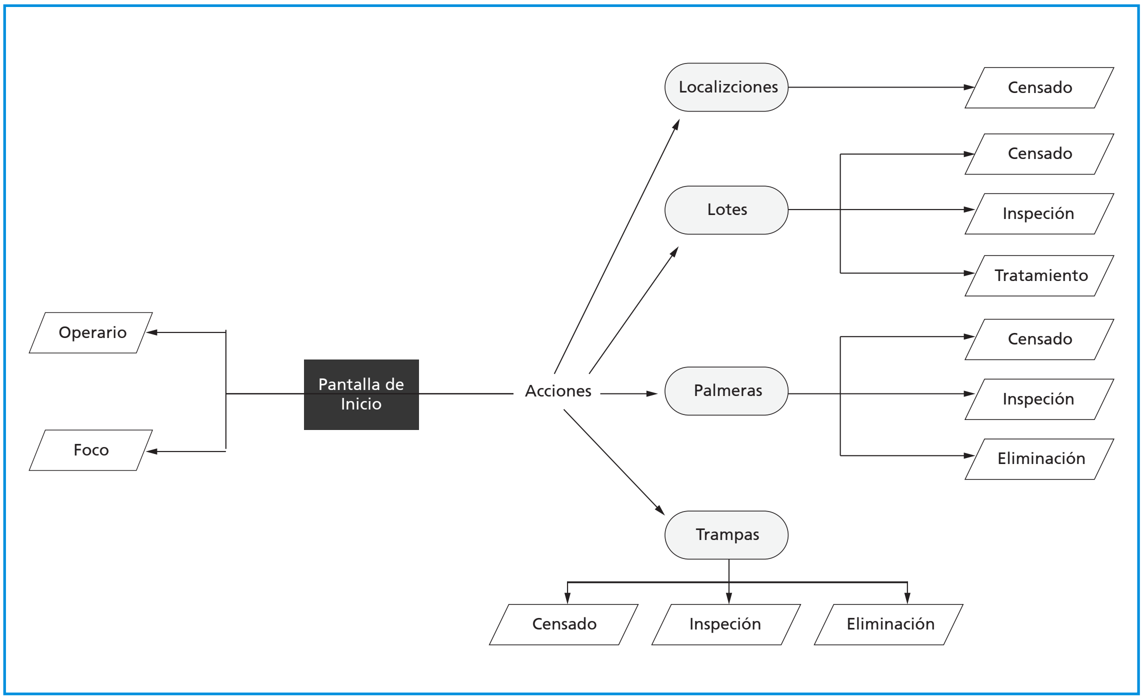
2.2 Mobile application

For data collection in the field an application for mobile devices was developed. It was designed in a way that it was very difficult to make mistakes when entering data. In this way, a great efficiency and data quality was achieved.

It is very important, although it was not our case, that mobile application includes a web viewer and GPS since it facilitates the work organization in the field.

Each activity carried out in the field was registered through the mobile application. The worker after selecting the affected area and opening different screens could choose the element and activity to perform. The following figure (Fig. 13) shows schematically the screens that integrate the mobile application.

Figure 13. Mobile application screen



Usually, at the end of the week, each island team leader synchronized through internet the collected data. This data was stored on a web server. Subsequently, through an automated process these data were imported into the central database of the project.

2.3 Web application

In order to make more friendly and efficient the use of the database, a web application was developed. Through this application the following activities could be carried out:

- Data entry in the same way as with mobile application.
- Edit data in case of mistakes done in field data collection or, for example, when traps were moved it was possible to change the coordinates.
- Performing queries that provided the necessary information for decision-making.
- Generation of tables, graphics and automatic reports that supported the decision-making and were a great tool that facilitates communication.

2.4 Web viewer

The web viewer allowed observing and analysing all the spatial information generated by the field works. In this way, it was possible to observe the activities on a map:

- Stored data such as lots (blocks), affected palm trees, traps, farmer, nurseries, etc.
- Customized queries: Palm trees removed by date ranges, palms lot (block) 100 m around trap with catches, traps depending on the number of catches, traps with captures within a date range, etc.
- New layers: area occupied by affected palm trees and traps in each affected area, etc.

Lessons Learned

After working with this application some necessary improvement were found:

- Using open source software due to the cost, flexibility and quality.
- The mobile application with GSM mobile data service made it possible to have data almost in real time.
- Viewer in mobile application: It is very important for organizing the field works- including a planning module.
- The possibility to export to a spread sheet all web application's queries will improve the analysis capacity.
- Technicians training on the software to reduce dependence on the ITs.

Conclusions

In May 2016, the Canary Islands were declared a RPW free area. The GIS is considered an essential tool for the planning and effective coordination of the eradication pest program and has allowed:

- Data and spatial analysis for optimal decision-making.
- Efficient planning and use of resources, a critical factor for success when these are limited.
- Assessment of the program (results, achievement of objectives) and workers from readily available quality information.
- Improvement of the program's internal and external communication.

It can be said that the eradication of the *Rhynchophorus ferrugineus* in the Canary Islands wouldn't have been possible without these applications.

15. Advances in semichemical mediated technologies against Red Palm Weevil

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Abstract

The Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* male produced aggregation pheromone 'ferrugineol' (4-methyl-5-nonanol) was synthesized during the early 1990s and since then has been widely used in the RPW management strategy in both surveillance (monitoring) and mass trapping programs. A 65% increase in capture occurs when a related ketone (4-methyl-5-nonanone) is included in the lure. Synergism between pheromone and fermenting food bait is essential to enhance weevil captures. Trapping protocols with respect to trap design, trap density in the field, periodic trap servicing (change of food bait and water), and pheromone lure etc. impacts the efficiency of the trapping program. Furthermore, RPW pheromone traps capture only part of the weevil population in the field. However, trapping when used in conjunction with other IPM tactics is often sufficient to achieve significant levels of RPW control.

Recently dome shaped black colored traps have been found to record higher weevil captures, as compared to the traditional bucket trap. Synthetic kairomone (ethyl acetate, ethyl alcohol, ethyl propionate) when added as a component to the RPW food baited pheromone trap enhances weevil captures. In area-wide RPW-IPM programs, systematic collection and processing of weevil capture data is essential and could be realized by geo-referencing the traps and use of the Radio Frequency Identification (RFID). Weevil captures in RPW pheromone traps provide a valuable data to decision makers to assess and validate the RPW control program.

In severely infested plantations a higher trap density of more than one per hectare could substantially reduce weevil population during peak adult activity. However, periodic replacement of the food bait and water is a major constraint in increasing the number of pheromone traps in the field. Service-less trapping options based on 'attract and kill' and use of a dry trap based on 'electro-magnetic radiation' have been found promising in Saudi Arabia and India as an additional component of the RPW-IPM mass trapping program. Incorporating RPW repellents (methyl salicilate, α-pinene, 1-octen-3-ol & geraniol) in a 'push-pull' strategy with pheromone trapping for palm protection needs to be explored.

This presentation gives an overview of advances in semiochemical mediated technologies against RPW

Key words: Red palm weevil, trapping, pheromones, repellents, management

1. Introduction

The Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) is a cryptic pest that has expanded its geographical and host range during the last three decades, threating palm species worldwide (Giblin-Davis *et al*., 2013). It has severe economic consequences to coconut and date palm farming in South and South-East Asia and the Near-East and North Africa, respectively besides infesting a large number of the canary island palms in the EU region (Al-Dosary *et al*., 2016, Dembilio and Jacas, 2012).

Semiochemicals are well known management tools for cryptic insect species. Despite their significant role in the behavior of practically all arthropods, pheromones are currently known for only a few palm pests among which RPW is important (Soroker *et al*., 2015). With the discovery and synthesis of the male aggregation pheromone (ferrugineol), during the early 1990s (Hallett *et al*., 1993) RPW has been managed employing an Integrated Pest Management (IPM) strategy where pheromone trapping is widely used in monitoring/surveillance and mass trapping programs (Abraham *et al*., 1998). In the recent years there have been improvements in the trap design, data collection and transmission through smart traps, use of dry traps and also in the application strategies involving attract and kill, attract and infect and the identification of RPW repellents that could be deployed in a push-pull strategy. Recently, Soffan *et al*., 2016 silenced the olfactory co-receptors for the RPW pheromone and proposed RNAi mediated control technologies to disrupt olfaction of this pest.

2. Pheromone trapping

With the synthesis of the male produced RPW aggregation pheromone (4-methyl-5-nonanol) by Hallett *et al*., 1993, mass trapping of adult weevils using food baited pheromone traps (Four-window bucket trap: 5-10L capacity) is widely practiced. Adopting the best trapping protocols (Hallett *et al*., 1999, Faleiro, 2006) with respect to trap design, food bait and lure, trap placement, servicing and density are essential to sustain the trapping efficiency (Hallett *et al*., 1999). RPW pheromone trap captures are female dominated usually two females captured for every male weevil trapped (Faleiro, 2006). Furthermore, only a part of the adult population is captured by RPW pheromone traps and therefore trapping needs to be combined with other IPM tactics.

In an area-wide operation with several hundred traps, regular trap servicing (replacement of food bait and water) becomes tedious and expensive and restricts the enhancement of the trap density in areas with high weevil activity, there by compromising the efficiency of the IPM strategy. Co-host attractants (ethyl acetate, ethyl alcohol, ethyl propionate, pentan-1-ol, 2-methoxy-4-vinylphenol and gamma-nonanoic lactone: Soroker *et al.*, 2015) when used in food baited RPW pheromone traps increase weevil captures several fold. Studies carried out in Saudi Arabia with service-less pheromone trapping options including 'attract and kill' and also the dry trap that operates on 'electro-magnetic radiation' have been found promising.

2.1 Trap design, and placement

Four-window bucket traps (5-10L) have been commonly used to trap RPW due to their operational ease in servicing (food bait replacement and insecticide renewal) and also trapping efficiency. Recently however, black coloured traps (Al-Saoud, 2013) and also the dome shaped trap (Picusan™) have been reported to capture more weevils as compared to the traditional bucket bucket traps (Vacas *et al.*, 2013). Both the bucket traps and the conical dome shaped traps have to be serviced at fortnightly intervals when the food bait and water is renewed. Servicing the dome shaped trap could be tedious and time consuming as compared to the bucket trap. During trap servicing data on weevil captures is also recorded. The possibility of data collection and transmission on a 24x7 basis using smart traps has also been reported recently (Potamitis *et al.*, 2009). A rough outer trap surface is recommended to facilitate entry of arriving weevils into the trap. Placing RPW pheromone traps on the ground away from young palms in the susceptible age group (< 20 years old in case of coconut and date palm) offers a landing surface for the attracted weevils, which later crawl into the traps. RPW pheromone traps may also be hung on trunks of mature palms at waist height or placed on 1m palm stumps hollowed in the centre.

2.2 Trap components (lures, food baits, co-attractants) and trap servicing

A wide range of RPW pheromone (ferrugineol) lures are available in the market. A related ketone (4-methyl-5-nonanone) increased weevil captures by 65% (Abozuhairah *et al.*, 1996). Ideally a lure should last long in the field and RPW pheromone lures have been reported to have a three month field longevity when traps are placed under the shade (Hallett *et al*., 1999) recommended a release rate of 3mg ferruginol per day.

Only when pheromone is combined with food odor is the attraction significantly more than to either pheromone or food (Faleiro, 2006; Hallett *et al*., 1999). Fermenting food baits are essential for sustaining the efficiency of RPW pheromone traps and is known to enhance weevil captures of RPW pheromone traps (Oehlschlager, 2016). In an area-wide operation where mass trapping is practiced it would be advisable to use a food bait that is not only efficient, but also readily available and not costly. Retaining captured weevils in the trap is essential. In this context, odorless insecticide / detergent is added to the food bait and water to kill the trapped weevils and prevent escapes (Oehlschlager, 1994; Rochat, 2006) while insecticide-free funnel traps have also been reported to be effective in retaining captured weevils (Hallett *et al*., 1999). A possible additive to increase the longevity of food in palm weevil traps is high boiling, non-toxic, propylene glycol (Oehlschlager, 2006).

Efficiency of the traps needs to be sustained by regular (bi-weekly) replacement of the food bait and water (trap servicing). In an area-wide operation with several hundred traps, this becomes tedious and expensive and restricts the enhancement of the trap density in areas with high weevil activity, there by compromising the efficiency of the IPM strategy. Ethyl acetate is a known co-attarctant (kairomone) when incorporated in food baited RPW pheromone traps generally increases captures by a factor of two to five (Oehlasclager, 2016). RPW catches increased two-fold with the 1:3 ethyl acetate/ethanol blend compared to aggregation pheromone alone, which indicates the importance of ethanol in the synthetic kairomone blend (Vacas *et al*., 2014). Co-attractants based on fermenting compounds, ethyl acetate and ethanol, could improve the attractant level of ferrugineol and potentially replace non-standardised natural kairomones in RPW trapping systems after further optimisation of their proportions and doses (Vacas *et al*.,2016). The most attractive traps at present are those containing fermenting food and emitting both pheromone and ethyl acetate. Pheromone is usually emitted at 3-10 mg/day, food is added at the rate of 150-350 grams and ethyl acetate is evaporated at the rate of 200-400 mg/day (Oehlschlager, 2016).

2.3 Trap density

Oehlschlager (1994) recommended a trap density of 1 trap per ha in mass-trapping programs. RPW can be effectively monitored using 1 trap per 100 ha (Abraham *et al*., 2000). In monitoring programs 1 trap could be set at every 5 to 10 kms along motor able roads could be adopted. However, trap density in both monitoring and mass trapping programs would be governed by the extent of human resource available for trap servicing and also the weevil activity in the field.

In case of persistent weevil captures in monitor traps and or also if infestations are detected, mass trapping could be initiated at 1-4 traps/ha (Faleiro *et al.,* 2011). In Israel, monitoring of RPW was carried out using 1 trap per 3 ha, while mass-trapping the pest was undertaken at a trap density of 10 traps per ha, in infested plantations of 2200 ha (Soroker *et al*., 2005). Often adding of traps beyond 1 trap/ha in mass trapping programs is not possible due to difficulties associated with periodic trap servicing. In this context, studies carried out in Saudi Arabia with service-less pheromone trapping options including 'attract and kill' and also the dry trap that operates on 'electro-magnetic radiation' have been found promising and elaborated below.

3. Semiochemical mediated RPW management strategies

- ***Attract and Kill***

  Attract and Kill (A&K) technology has been widely used to control insect pests in a wide range of crops worldwide (El-Shafie *et al*., 2011), showed that the efficiency of this method was comparable to the traditional food baited-pheromone traps. During 2015-2016, this technology was evaluated on a large scale for palm protection in RPW infested date plantations in Saudi Arabia and on oil palm in India using RPW-A&K products (Hook-RPW ™ and Smart Ferrolure ™) formulated as a paste using ferrugineol and cypermethrin. The card system of Smart Ferrolure ™ combines the pheromone lure: ferrolure + ethyl acetate attached to a card laced with cypermethrin.

  In a severely infested 10 ha RPW plantation in Al-Qassim, Saudi Arabia Hook-RPW ™ deployed at 400 dollops (4g each) / ha resulted in 290 weevils being attracted and killed by 10% of the points set in containers during the trial period of 23 weeks between 09 November, 2015 and 11 April, 2016. Furthermore, weevil captures in the traditional food baited traps (1trap/ha) were lower in the experimental plot with A&K as compared to the control plot without this component, which is indicative of the role played by attract and kill in eliminating the adult RPW population, without the deployment of additional pheromone traps that would need bi-weekly servicing (Faleiro *et al*, 2016a)

In other trials involving Smart Ferrolure™, results showed that both the paste and card systems attracted and killed RPW adults as evidenced from the dead weevils in the points set in containers in the trial sites in Saudi Arabia in date palm and in India on oil palm. The paste formulation killed nearly twice as many weevils as recorded in the containers as compared to the card system, which could be to the fact that the card system was installed at only 30 points/ha as compared to the paste formulation of Smart Ferrolure™, which was tested at 250 points/ha. While results with the paste were encouraging, the card exhibited significantly low killing capacity in about 45 days after exposure in the field, probably due to accumulation of dust on the card in Saudi Arabia that prevented contact of attracted weevils to the insecticide and also washing away of the insecticide due to rain in India (Faleiro *et al*., 2016b).

- *Dry trap*

Soroker *et al*., 2015 identified several RPW host attractants *viz.* ethyl acetate, ethyl alcohol, ethyl propionate, pentan-1-ol, 2-methoxy-4-vinylphenol and gamma-nonanoic lactone. These are potential pheromone synergists that could be used to develop stand-alone RPW pheromone lures that may not need the support of natural food baits that could eliminate the need of frequent replacement of the food bait and water in the trap. The Electra Trap™ , which is a dry trap is dome shaped, with the pheromone and a co-attractant (ethyl acetate). This trap was tested for its efficacy against the traditional food baited bucket trap and the Picusan™ trap in Saudi Arabia. Results revealed all treatments were statistically similar. It is relevant to point out that the Electra Trap™ does not need any servicing for at least four months and its trapping efficiency is similar to the traditional food baited trap where the food bait has to be renewed at least once every two weeks. Data collection on weevil capture for decision making is vital in an area-wide RPW-IPM program. In this context the possibility of making the Electra Trap™ smart for automatic transmission of weevil capture data needs to be looked into.

- *Attract and infect*

This strategy could assist in augmenting biological control efforts against RPW using entomopathogenic fungi (EPF) set in a RPW pheromone trap. The trap should restrain the insects long enough to be infected but also allow them to leave the treatment location in a healthy enough condition so as to find a mate and transfer the pathogen (Soroker *et al*., 2015). *Beauveria bassiana* solid formulation with high RPW pathogenicity and persistence could be applied both as a preventive and curative treatments for RPW control (Guerri-Agullo *et al*., 2011). Recently Hajjar, 2015 through laboratory and semi-field cage studies showed the possibility of infecting RPW adults with *B. bassiana* using pheromone traps.

- *RPW repellents*

  A new dimension to the use of semiochemicals for the sustainable management of RPW in date palm could be the possibility of identifying and deploying insect repellents with pheromones in an area-wide programme involving a push-pull strategy (Al-Dosary *et al*., 2016). α-pinene, singly or in combination with methyl salicylate or menthone are potential RPW repellents (Guarino *et al*., 2013), that need to be evaluated for palm protection particularly in the canary island palm where RPW repellents could be deployed in the crwom and the pheromone trap at the ground in a push-pull strategy.

4. Success Stories

Pheromone trapping by itself is an excellent monitoring tool in RPW surveillance programs but has to be deployed in a RPW control program with other IPM tactics including inspecting palms to detect infestations, preventive and curative treatments, removal/eradication of severely infested palms etc. There are several examples of using RPW pheromone traps to successfully control the pest in a RPW-IPM program (Al-Dosary *et al*., 2016, Oehlschlager, 2016). Noteworthy among these being the eradication of the pest in the Canary Islands where no new weevil captures/infestations were recorded since 2013 and the island was declared free of RPW during May, 2016. In Mauritania too, pheromone trapping along with the semiochemical mediated tactic of 'attract and kill' and other RPW-IPM components including active farmer and other stakeholder participation in the program has controlled the pest within a year of implementing the strategy during March, 2016 in Tidjikja. Also, analysis of RPW-IPM data in Al-Ahsa Saudi Arabia showed that intensive mass trapping of RPW that was initiated in October, 2009 in the Al-Gowaybah (1,104 ha) resulted in a 86% decline in captures in 2012 when compared to total captures for 2010. Additionally, over the same time period, insecticide application and palm eradication rates dropped by 91% and 89%, respectively (Hoddle *et al*., 2013).

5. Conclusions

Semiochemical mediated strategies against RPW could be refined by;

- Evaluating and deploying service-less trapping options involving i) attract and kill as an additional component of the RPW-IPM mass trapping programme and ii) dry trap using electro-magnetic technology integrated with the smart trap.
- Develop a push-pull strategy using RPW repellents.
- Managing mass trapping through the use of mobile applications integrated with GIS for efficient data collection, transmission and decision making.
- Involving farmers in the mass trapping programs.

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16. Advances in semiochemical mediated technologies against Red Palm Weevil (Straps, pheromones, kairomones, dry traps, attract and kill repellents)

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Abstract

The red palm weevil *Rhynchophorus ferrugineus* L (RPW), is a key pest of several economically important palms in Far East Asia, South Asia, Middle East, North Africa and European countries abutting Mediterranean Sea. Conventional food baited traps attracted adult weevils and was used as a method in the control of RPW in South Asia in 1970s. After the discovery of male aggregation pheromone (4-Methyl-5-nonanol and 4-Methyl-5-nonanone) in early 1990s, the synthetic pheromone lures were subjected to several field tests and very efficient pheromone traps were developed and adapted to the prevailing field conditions and made as a component of integrated pest management (IPM). Subsequently the trap design, color, density, foods and other parameters were standardized to enhance the trap capture rates. Addition of Kairomone (Ethyl acetate) to the pheromone lures significantly augmented the trap catches and became an integral part of the trapping systems.

The pheromone trapping was useful for mass trapping to remove large number of both female and male adult weevils from the fields. Apart from mass trapping, the traps were also used to monitor the pest presence in some areas. The pheromone trapping requires period servicing of each trap by the replacement of fresh food and water. Due to constraints in manpower, transport facilities, and other logistics, the periodic servicing has become a challenge for the trap users and service providers. Hence, the search for alternate pheromone mediated methods that were devoid of servicing are explored by various researchers resulting in the development of dry trap or smart trap. Besides the pheromone traps other methods like attract and kill method and use of repellents are in various stages of experimentation and adaption.

17. Socioeconomic studies and approaches to involve farmers in the fight against the Red Palm Weevil (RPW)

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Abstract

Date palms are growing in oasis that were traditionally managed by communities of farmers and where the crucial water resource was generally common. This management has evolved considerably during the last decades.

During this period, the sharing roles of State and farmers have passed through different phases. In recent years, the general tendency has been to a withdrawal of the State. At the same time, we observe in many countries a rapid and huge increase of date palms plantations that has resulted in important movement of palm offshoots and very often to an overexploitation of the water resources and a degradation of water and soil quality. These factors had and still have direct and indirect consequences on the RPW issue: introduction and large spread of infested offshoots in nearly all the countries; degradation of the traditional oasis farming system that leads part of the farmers to neglect their palms.

In the fight against the RPW, we can distinguish three main organizational models according to the countries: the State handles all the activities and the farmers are usually not or very little involved; the farmers have to assume all the fight activities with very limited or no assistance; in rare cases, farmers are totally involved with the help of the State and of national or international organizations.

As demonstrated by the uncontrolled situation of the RPW in most of the countries, the two more frequent organizational models are not adapted to the RPW management. From the technical perspective, the control of the RPW is based on a set of activities perfectly established for a long time: frequent inspection of the palms for early detection and on site immediate sanitation, mass trapping, targeted preventive treatments and cultural measures.

As the implementation of these activities requires frequent and quick interventions, huge organization and important means are necessary when the farmers are not involved. If they were involved, trained and supervised, they, or their workers,

could perfectly realize all these activities as they can be implemented with simple and low-cost equipments and products. The involvement of the farmers requires a multidisciplinary approach taking into account the socio-economic component of the problem.

We propose a participatory local diagnosis to dispose of a better knowledge of the socio-economic context on the main following points: typology of the farming systems, identification of organizational weaknesses, evaluation of economic consequences of the RPW damages, assessment of the farmers' knowledge regarding the pest and its control. We consider that the use of satellites or other images would be of great help to locate the farms and establish some of their characteristics. All these data and other information on the farms will be integrated in the GIS of the RPW management project.

Based on this better knowledge, the objective is to identify the main constraints for the involvement of the farmers and to elaborate, with them and all the other concerned actors. proposals to overcome these constraints. We anticipate the importance of proposals on the following points: incentives and coercive measures, RPW-free palms availability, training. Regarding this last point, we propose the Farm Field School approach.

Key words: socioeconomic approach, farmers' involvement; local participatory action plan; capacity building; RPW eradication.

1. Introduction

Palm trees are well established in the NENA Region, both as date palms in the oasis and ornamental palms in urban areas; they are the target today of a deadly pest that can kill them in less than one year: the Red Palm Weevil (RPW).

The direct and indirect impacts on the date palms and on the production of dates, and consequently on farmers' subsistence as well as on the environment are serious in the palm groves of most countries in the Middle East, except for Sudan where no case has been reported, and in Iraq where it was first identified only few months ago.

In North Africa, it has not been reported in Algeria, it is present only around Tripoli and Tobruk in Libya, while in Mauritania only one oasis has been affected.

In Morocco and Tunisia, RPW has induced major damage on ornamental palms in some municipal areas nearby the Mediterranean Sea and represents a major threat for the oasis in the Southern areas, in case of accidental transportation of the pest.

Therefore, the controlling and eradicating this pest constitute a real challenge for all of us at different levels: citizens, municipalities, farmers, researchers, developers, NGOs and decision makers.

Technical and organizational measures taken in countries where RPW was introduced and disseminated after the import and spreading of infested palms have not been successful so far; except for some positive results where this pest was slowed down, failure was the rule in all other areas. RPW attacks are extending and striking an increasing number of healthy and vigorous palms.

Difficulties faced are not really technical, as measures that must be taken to fight against RPW are sufficiently known and controlled by specialists in charge of plant protection. However, to implement these measures, stakeholders, mainly farmers, have in general been neglected, and the role that they can play in their success has been disregarded. This constitutes the main reason for the present failure. Therefore, a multidisciplinary approach, including the technical, social, economic and environmental aspects of this issue, is no more a choice but has become an evident necessity.

This article aims at highlighting the contribution of human sciences and the need to integrate socioeconomic approaches in any program developed for the fight against this fatal pest, and hence position farmers and local partners along with all other partners at the heart of the anti-RPW approach.

In this framework, we will try to answer four fundamental questions:

1. What can be the contribution of social sciences to improve the efficiency of programs in the fight against RPW?
2. What role can be played by local partners, mainly farmers, in this process?
3. Which diagnoses and socioeconomic studies are considered crucial to improve the efficiency of RPW fight programs and to involve local actors?
4. How to reinforce local actors' capacities to truly involve them in anti-RPW programs?

2. Evolution of oases' management modes

Oases are defined as socio-agro-ecological systems. They are the result of a trilogy: water resources, land and rural communities. They also host small farming activities, partly for self-subsistence, but also for trade. However, traditional community management systems could not resist against recent developments. Consequences on the management of natural resources are notorious.

Following is an account of the evolution of oases management modes, which have gone through three fully distinct periods:

- Community management phase

Oases were created and maintained until the middle of the 20th Century thanks to community organization patterns in terms of the right of access and use of the resources, and in conflicts resolution. A typical example of this genuine organization mode is the system of rules set by oasis communities to mobilize and use water, a vital resource that is strictly limited in oases. The oasis community was also in charge of protecting the oases against all sorts of threats: natural (sand dunes, pests, diseases, etc.), or anthropic (vandalism, ...).

- State management phase

This phase started in the sixties of the last century. It was marked by a strong intervention on the part of the State. The socio-political space was dominated by the nation-State and the emergence of State and para-State structures for the management of oases, resulting in the dislocation of community management and the decline of societal organizations. Community patterns were then replaced by "association" systems controlled by the State.

- State disengagement phase

The last three decades have witnessed a clear disengagement of the State in the management of oases. Collective and community rules for the management of natural resources have mostly been abandoned in favor of individual initiatives and market rules. The most striking expression of this trend is the unprecedented increase of new date palms plantations around individual water pumping stations, inducing a much higher trade of offshoots, hence the introduction and wide dissemination of RPW as we see it today.

During the last period, we saw the emergence in some oasis of active oasis associations playing major role at the local level. But, the problem of traditional oases management regarding the socioeconomic and ecological issues has been growing. It is mainly reflected in the qualitative and quantitative deterioration and degradation of natural resources, mainly that of water, land, biodiversity, and the progressive disappearance of favorable conditions for small farms, usually prevailing in oases.

These problems are further aggravated by climatic changes, the amplification of the desertification phenomenon and the proliferation of pollution spots.

The social, economic and ecological role of the oasis is today in danger. The living environment and subsistence means of the populations are affected, not to say seriously deteriorated. Entire oases are currently threatened to be abandoned and to disappear if nothing is urgently made to save them. The consequences are the impoverishment of small farmers in particular and rural exodus. Related costs required to reduce the disastrous effects on the environment and to increase of the population's resilience towards economic and environmental problems have increased.

The multiplicity of stakeholders, the lack of coordination mechanisms, a sectoral conception of management, the weakness of legal instruments, limited incentive measures, and the absence of sensitization and education programs represent factors that further complicate the situation. It is obvious that in this new difficult context, social, economic and cultural conditions are not very favorable for the fight against RPW. It is therefore imperative to know and thoroughly analyze these conditions in order to come up with solutions that may provide better conditions to succeed this fight.

3. Main national organizational models in the fight against RPW

We suggest in the following paragraphs a critical analysis of the different organizational models implemented at national levels for the fight against RPW:

- Observers farmer

In this model, public institutions are in charge of all activities related to the fight against palm pest. Farmers and their organizations are almost not involved at all.

- The farmer is left alone

In this case, activities for the fight against RPW are entirely left for farmers to look after, sometimes with very limited contributions on the part of the State, as the supply of insecticides!

Almost no country using any of these two models has been able to eradicate this plea or at least reduce its propagation, although considerable amounts have sometimes been mobilized. RPW dispersion is increasingly generalized and the number of infested palms is constantly growing.

- Engaged and participating farmers

In this third model, which is very rare in practice, local stakeholders are involved in the fight with the support of the State and of international organizations (FAO) or national structures. Experiences adopting this approach and integrating the socioeconomic aspect in their anti-RPW programs have generated very encouraging results that can be considered a success.

Consequently, the two main lessons that can be drawn from the analysis of the three organizational models are:

- Techniques for the control and eradication of RPW, ranging between frequent inspections to targeted preventive treatments, are fully known but no activity has been implemented to make them appropriated by the farmers;
- If local stakeholders, particularly farmers, were involved, trained and coached, they would perfectly be able to implement all or most activities planned in the RPW management program, with much better efficiency and at more reduced costs than in programs implemented by the Administration. These activities include one that may constitute a key action to rapidly eradicate the palm pest and can be very easily carried out by farmers or their workers: the frequent inspection of palm trees to detect infested palms at a very early stage.

4. How to integrate socioeconomic approaches and involve the farmers and other local stakeholders?

The analysis of different experiences in the fight against RPW shows that the involvement of farmers and local stakeholders could not be obtained and sometimes even not considered as only experts in plants protection or entomology were mobilized. The involvement of farmers along with all different concerned actors requires a multidisciplinary approach taking in consideration the socioeconomic component of the problem. Several issues can be raised with regard to this approach:

⇒ How to position the different stakeholders, most particularly the farmers at the core of this program and make them real actors with full ownership of RPW fighting activities?

⇒ What are the constraints that impede their real participation?

⇒ How to involve and motivate farmers?

⇒ How to support and reinforce local organizations in oases?

We suggest below some socioeconomic approaches aiming at the involvement of local stakeholders. In a first phase, it would be necessary to undertake some studies and participatory observation campaigns to examine the oasis management system and local active actors. Then we suggest other field actions that will confirm and reinforce the involvement of local stakeholders.

- Conduct a local participatory diagnosis of the situation in oases

One cannot involve field actors without properly knowing the socioeconomic context in oases. The participatory analysis is considered to be an elementary strategic observation tool, that will later help to improve and better focus the vision about the situation and its dynamics through a SWOT analysis – Strengths, Weaknesses, Opportunities and Threats.

Socioeconomic diagnosis

Data about oases

- Characteristics and economic, social, demographic statistics …
- Various inventories (palm trees, production, etc.)
- Mapping (thematic maps, etc..)

Consultation of the population and local actors

Farmers' opinions about identified strengths and weaknesses:

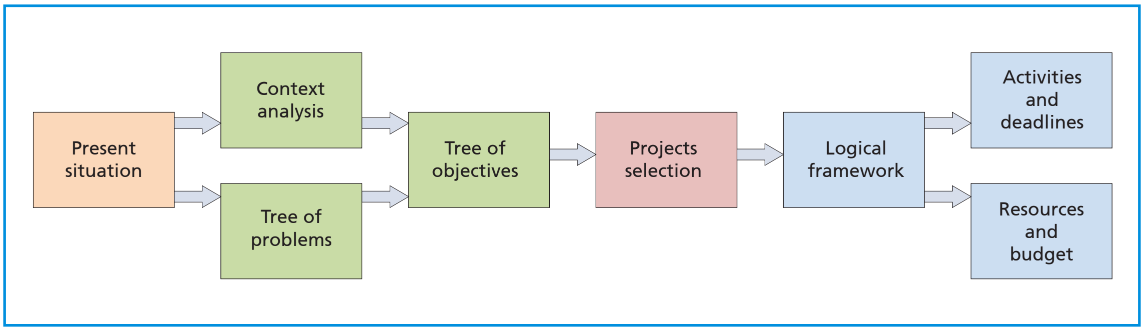
- Meetings in every oasis
- Interviews with resource people
- Surveys of the target population (landlords, workers, associations, cooperatives, etc...)

Participatory Diagnosis

Situation of the overall status of the oasis showing the main issues and specific resources, hence highlighting the main challenges (that need to be overcome) and the main objectives for the future fight against RPW

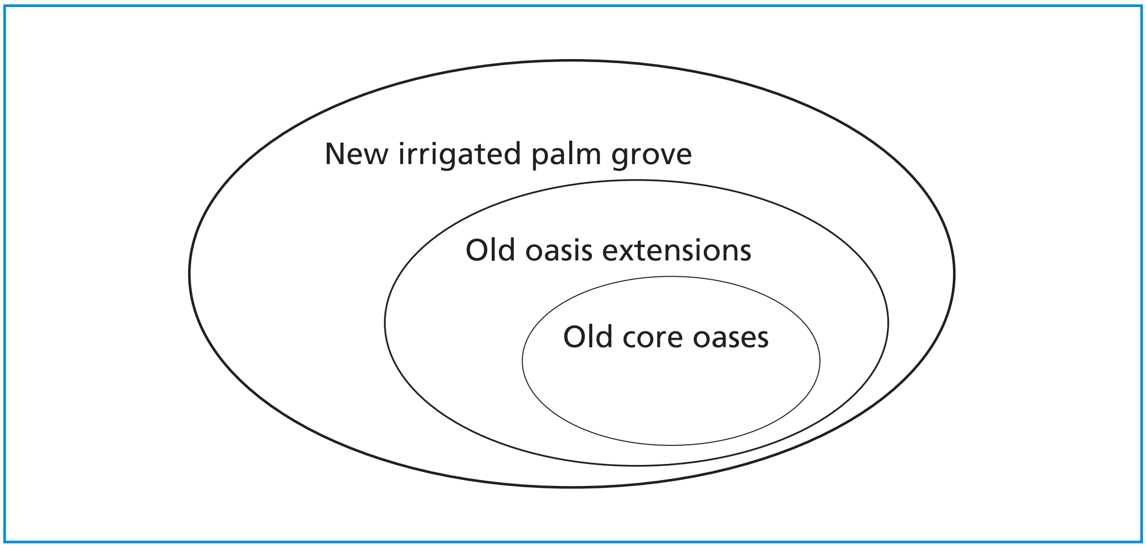
To undertake a local participatory diagnosis, several approaches for social facilitation and moderation can be suggested, such as panel discussions, brainstorming, simulation, role play, photo-language, etc…

The different methods should help to draw the entire project-program cycle starting with an analysis of the problematic situation, followed by the elaboration of a participatory action plan by country. The logical framework can define activities to perform, stakeholders' liabilities as well as human and financial resources that need to be mobilized.



- Identify the diversity and dynamics of oases

Any intervention program on a phytosanitary problem, RPW in this case, must take in consideration the diversity and dynamics of the palm trees environment. It is necessary to conduct studies in order to characterize and demarcate different areas (old core oases, old oasis extensions, new irrigated palm groves) and follow ongoing spatial dynamics.



- Define the zoning and typology of oasis farms

It is also necessary to identify the socio-agro-ecological zoning distribution and the typology of agricultural farms in order to characterize their socioeconomic operation (new large plantations/well maintained profit-making family gardens/leisure parks/ gardens with palm trees and nice villas/poorly maintained or neglected parks ….)

- Identify the different stakeholders and analyze their roles

The identification local stakeholders (farmers and their workers, local communities, associations, cooperatives, ventures, private sector, etc..) and the analysis of their roles represent major components in this approach. Before the design of an action plan, it is important to identify the roles played by the different stakeholders at the local level and to know how much they know about the parasite, fight practices, and risks inherent with the transfer of offshoots. It is also important to identify the weaknesses of the local organizations as well as resources they hold, and their needs in terms of capacity building.

- Evaluate the socioeconomic impacts of RPW in infested areas

The evaluation that will be carried out in the framework of the RPW management program aims at making the inventory of farmers and their plantations and making an evaluation of the direct and indirect impacts on farmers' subsistence means.

- Perform an analysis of the legal framework

The analysis of legislation in force related to oases aims at:

- Review the existing legislation (protection of oases, quarantine, …)
- Checking the legislation's enforceability;
- Identifying the need for new legislations …

Integrate socioeconomic data and information in the GIS

The different socioeconomic information collected in the different studies, diagnoses and investigations mentioned above must be integrated in a Geographic Information System (GIS) and in all decision-supporting tools that will be developed in the framework of the global program for the fight against RPW.

- Other measures

In addition to the proposed participatory studies aimed at integrating the socioeconomic component in the program to fight against palm pests and to involve local stakeholders, it is also necessary to promote and support:

- The gender approach;
- Implementation of incentives and coercive measures for farmers (awards for the early detection of pests, fines for non-compliance with regulations and for neglecting land parcels …). Legal measures must be developed with the close collaboration of all involved stakeholders, including farmers. This is crucial for regulations to be efficient.
- Creation of multidisciplinary pilot projects, including experts in human sciences, to work on the feasibility of involving farmers in the fight against RPW;
- Implementation of a capacity building program in favor of local organizations and improvement of interventions carried out by associations based around oases;
- Creation of farming schools to train farmers and agricultural workers;
- Establish networks bringing together local organizations, in order to develop common discourse and be better heard by the local authorities;
- Establish contract programs between the State, local communities and their partners;
- Study the different systems of offshoots supply and elaborate with the farmers a system of supply with certified plants

5. Conclusion

This article tries to highlight the socioeconomic perspective and contribution in the eradication of a plea threatening patrimonial systems and living sources for very large populations leaving in and from oases. The suggested approaches aim at properly positioning local stakeholders, particularly farmers, to be better involved in programs for the fight against RPW. It is necessary today to undertake a series of studies to clarify the socioeconomic impacts of oasis, which are still unknown, and hence contribute to decision making. Other actions are also recommended to reinforce the capacities of local stakeholders and set up a mechanism for the exchange of good practices.

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F. Abstracts of the presentations presented in CIHAEM side session:

1. The RPW as vector of bacteria, fungi and acari
2. The RPW infestation elicit a control-factor repressive environment
3. Host-plant species and management consequence over infestation, damage and control
4. Weevil larvae diet: histophagy vs plasmophagy
5. Putative glandular territories associated with Rhynchophorus ferrugineus ovipositor.
6. Role of Beauveria bassiana on plant defence, biocontrol and insect behaviour modification

1. The RPW as vector of bacteria, fungi and acari

Porcelli F.[1,4,5], Scrascia M.[2], Pazzani C.[2], Pollastro S.[1], Di Palma A.[3], Russo V.[4], Roberto R.[1], Salerno M.[1], Diana L.[1], Valentini F.[4], Djelouah K.[4]; 1 DiSSPA UNIBA Aldo Moro, 2 Dipartimento di Biologia UNIBA Aldo Moro; 3 Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente UNIFG, 4 CIHEAM-IAMB, 5 CNR-IPSP Bari)

Adults of *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera Curculonidae) usually carry several associate or symbiotic organisms. We present evidences of Bacteria, Fungi (both yeast and hyphal) and Acari regularly found on the weevil while they actively disperse. In this contribution we consider the presence of: Bacteria belonging to the species *marcescens* or *nematodiphila* of the Genus *Serratia* (Enterobacteriaceae); the yeast *Candida tropicalis* (Berkhout, 1923, Fungi Saccharomycetaceae) and *Hyphopichia burtonii* (Boidin, Pignal, Lehodey, Vey & Abadie) Arx & Van der Walt (Fungi Incertae sedis); Acari Uropodina belonging to the species *Uroobovella marginata* Koch, 1839 and *Centrouropoda almerodai* Hiramatsu & Hirschmann, 1992 and a species of Pleosporaceae tentatively identified as component the Genus *Curvularia* Boedijn, 1933.

The scrutiny of wild and reared material made clear that during oviposition the RPW infects the eggs and the egg chamber walls with *Serratia* and yeasts, while the egg chamber plug with *C. tropicalis* and *H. burtonii*, mostly. Both sexes of the weevil airborne the Acari as hypopi that are exposed for *U. marginata* and hidden underside the elytra for *C. almerodai*. Both Uropodina species bring conidia firmly and partially melted into their cuticle but the viability of the fungus is still to be demonstrated. The given evidences suggest to consider the story of RPW not the introduction and subsequent invasion of a single species, but the biologically coordinated actions of a guild of symbionts.

2. The RPW infestation elicit a control-factor repressive environment

Scrascia M.[1], Pazzani C.[1], Valentini F.[2], Oliva M.[1], Russo V.[2], D'Addabbo P.[1], Stallone G.[3], Roberto R.[4], Porcelli F.[2,4,5]; 1 Dipartimento di Biologia UNIBA Aldo Moro, [2] CIHEAM-IAMB, [3] Volatome Srl, [4] DiSSPA UNIBA Aldo Moro, [5]CNR-IPSP Bari

Insects and Bacteria can engage symbiotic interactions that profoundly affect the fitness of the actors. Focusing on the facultative symbiosis among the Weevil and the Red Pigment Producing Bacteria (RPPB) *Serratia marcescens* (Enterobacteriaceae), its strictly related *S. nematodiphila*, *Candida tropicalis* (Berkhout, 1923, Fungi Saccharomycetaceae) and *Hyphopichia burtonii* (Boidin, Pignal, Lehodey, Vey & Abadie) Arx & Van der Walt (Fungi Incertae sedis) we suggest that this association has certainly driven their reciprocal adaptation. Our studies demonstrate the regular association of RPPB and yeasts with the plant - on egg chamber and pupal case walls - and the insect cuticle during oviposition, larval and pupal steps. By dissecting we also demonstrated the occurrence of microorganisms either in larval or adult RPW gut or into the female reproductive apparatus lumina. Dissecting the reproductive apparatus of ready-to-ecdysis female pupae revealed them to be devoid of microorganisms. The latter are re-acquired while teneral adult females rest 3-5 days in their pupal cases. A first metabolomics study by GC HFTOF MS to the compounds resulting from anaerobic one-larva breeding revealed high EtOH levels, and several other classes of compounds probably resulting from microorganism's metabolism. Moreover, in plate experiments show a clear antimicrobial activity of RPPB against Gram positive (*Bacillus megaterium*, *B. pumilus*, *Staphilococcus aureus*, *Lysinibacillus* spp., *Paenibacillus* spp.) and Gram negative (*Salmonella typhimurium*, *Klebsiella pneumoniae*, *Escherichia coli*) bacteria possibly due to prodigiosin.

The presence of the same weevil-borne RPPB & yeast in infested palm tissues and the heat increment induced by facultative fermenting ability of *Serratia*, as demonstrated by API20E system tests, close the circle of this presentation. We suggest that RPW infestation induce an environment that repress RPW biological control-factors because is intensely bacterized, hot, antibiotic, fermenting and rich in EtOH and organic acids.

3. Host-plant species and management consequence over infestation, damage and control

Al-Shalchi H.Y.[1], Valentini F.[2], Djelouah K.[2], Diana L.[3], Porcelli F.[2,3,4]; 1 State of Agriculture research: Iraq Ministry of Agriculture, 2 CIHEAM-IAMB, 3 DiSSPA UNIBA Aldo Moro, 4 CNR-IPSP Bari.

Ryhnchophorus ferrugineus has shifted on several economic palms during his invasion of new territories. Each shift was possible because of particular adaptation to newly encountered host morphologies and anatomies, giving symptoms and damages more dependent on the host plant than on the pest. Here we discuss the connections among the RPW behaviour and the host palm species, action and economic control thresholds and harmfulness of the different damages. The water content measurement in *Phoenix canariensis* in south Italy led to estimate in about 100 litres per metre height of central cylinder of the trunk. This is possible because the great extension of the starchy parenchyma among the plant bundle. We consider the amount of water and starch as one of the prominent factor driving the entity and the lethality of damages because it facilitates the weevil-borne yeast and bacterial rotting. On the other hand, this large amount of water can be used as an insecticide secondary carrier to get the final dilution and this fact reduces the misuse of pesticide dose in correlation with palm water contents. On this specific idea, the patented (BA2009A000014 int. code A01G2900) injectors works year by year to deliver the insecticide into the palms considering safety for the operator and environment. Finally, we discuss the effectiveness of the preventive and protective strategy adopted in CIHEAM – IAMB.

4. Weevil larvae diet: histophagy vs plasmophagy

Suma P.[1], Mazzeo G.[1], Russo T.[2], Salerno M.[3], Porcelli F.[2,3,4]; 1 Di3A UNICT, 2 CIHEAM-IAMB, 3 DiSSPA UNIBA Aldo Moro, 4 CNR-IPSP Bari

Comparing *Phoenix canariensis* infestation symptoms given by *Rhynchophorus ferrugineus* and *Paysandisia archon* we were intrigued by outstanding differences among the foci infested by the Curculionidae and the Castniidae. Actually, major differences occur in bacterial rotting halos on the tunnels walls and in the palm matter eventually filling the tunnels lumina. Halos, and consequent extensive rotting, do exist in RPW infestation but miss in the caterpillar tunnels. In the same way chewed/digested palm matters are expelled by *P. archon* caterpillars from tunnels that are empty and clean, while a large amount of long plant fibres matter fills the bores opened by RPW grubs. A visual analysis of the palm matters from *P. archon* and RPW reveals the very diverse size of the debris originating from the infestations of the two different pests. The evidences suggest that almost any of those due to RPW activity may result from a digestive process and from a gut transit. Visual and polarized light study of the gut content of several RPW larvae in different ages strongly support the interpretation that grubs while feeding select plant parenchyma as food but discard fibres that are palm vessel bundle. We discuss this arguments in relation to the choose of the proper insecticide a.i., the formulate and the distribution technique of the chemical control means.

5. Putative glandular territories associated with *Rhynchophorus ferrugineus* ovipositor.

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While accurately scrutinizing RPW female reproductive apparatus for external and exposed pouches harbouring Bacteria, we encountered two inflatable trunk cone-shaped sac-like organs that rise from the dorso-lateral sides of the ovipositor. Direct observation and study by macrophotography, stereoscopy, bright field light microscopy, SEM and Cryo-SEM revealed a coherent among methods and rather intriguing morphology of the parts. Ventral cuticle of the cones is membranous and ornamented by microtrichia plus scarce seta. Dorsal external surface of trunk cones shows some degree of sclerotization and is intensely pitted by single or grouped (2-20) apparent ducts openings. Internal cuticle surface shows, after bleaching with a mix of NaOH/SLS/soaps, round ridges corresponding to the external pits with confluent ducts resembling end apparatus of glands. Being the first evidence of such structures, chemical electrophysiological, and behavioral investigations are in progress in order to clarify their possible role in the intraspecific chemical communication of RPM and identify possible behaviourally-active compounds.

6. Role of Beauveria bassiana on plant defence, biocontrol and insect behaviour modification

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Palms have landscape, historical and economic importance worldwide. Their susceptibility to pests and pathogens has increased due to plant trade globalization/ global changes. The epidemics of the red palm weevil infestation in Spain and worldwide is a good case study. Fungal antagonists have a great potential in the sustainable management of biotic stresses in palms. The entomopathogenic fungus *Beauveria bassiana* is prevalent in mediterranean soils. *B. bassiana* strains in SE Spain infect naturally RPW. Some of these strains have been tested successfully against the RPW under lab, greenhouse and field conditions. Recent studies using GIS and acoustics show that *B. bassiana* stops spread to *B. bassiana* treated palms. The fungus also modulates the immune response of palms and have therefore direct and indirect roles in biocontrol of RPW, other palm pests and diseases. Fungal parasites of invertebrates bear strong similarities and are enhanced by chitosan, a derivative of chitin. This is a biopolymer derived from chitin a structural component of invertebrate cuticles. Omics can help to devise sustainable and enhanced ways to manage invertebrate pests (nematodes and insects) such as the RPW.

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